

TECHTEST:

An Excel-Based Tool for Evaluating Techno-Economic, Energy, and Carbon Impacts of Early-Stage Technologies

A Tutorial from the U.S. Department of Energy (DOE)



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A Tutorial from the U.S. Department of Energy

Welcome to the DOE's video tutorial series on energy and cost analysis!



Jordan

In this module, we will:

- *Describe TECHTEST, an Excel-based tool that offers a framework for conducting an abbreviated Life Cycle Assessment (LCA) and Techno-Economic Analysis (TEA) of an emerging technology compared to its industry benchmark*
- *Go through an example scenario to explore the tool's features*

Welcome to the DOE video tutorial series on energy and cost analysis. In this module, we will:

- Describe TECHTEST, an Excel-based tool that offers a framework for conducting an abbreviated Life Cycle Assessment and Techno-Economic Analysis of an emerging technology compared to its industry benchmark.
- We will also go through an example scenario to explore the tool's features.



The tool has been developed to clearly help demonstrate the benefits of an emerging technology

U.S. DEPARTMENT OF ENERGY (DOE) OFFICE OF ENERGY EFFICIENCY AND RENEWABLE ENERGY (EERE)

Techno-economic, Energy & Carbon Heuristic Tool for Early Stage Technologies (TECHTEST) ENERGY

Version 1.0

Release: February 19, 2023

What can I expect from TECHTEST?

- TECHTEST is a tool that collects specific categorical cost, energy, and emissions data about a new technology and the associated benchmark technology for comparison.
- TECHTEST will develop a series of charts and tables that will project the economic and sustainable viability of the product compared to its comparable current market technology.

There are two ways to fill out TECHTEST:

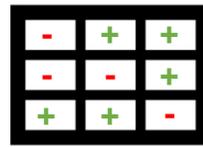
- **Full Analytical Approach:** Review each section of the lifecycle separately, enter more granular data. (Recommended for first time users)
- **Rapid Data Entry Approach:** Abbreviated approach, little to no explanation of steps. (Recommended for multiple scenario testing)

TECHTEST Data

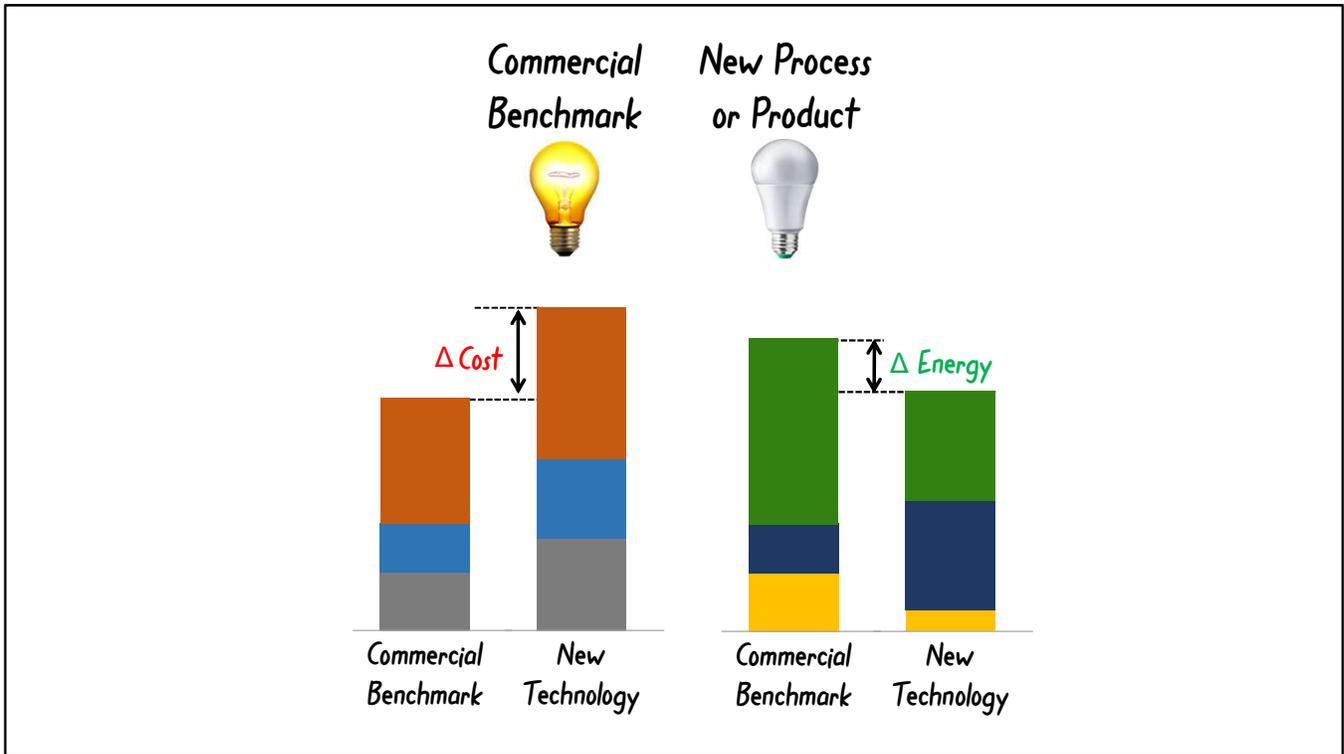
- TECHTEST utilizes CO₂e and costs associated with materials and energy sources to fill out the back-end of the calculation. The cost vectors and corresponding sources can be found in the link below:
[Link to energy/cost data tables.](#)
[Link to global warming potential data tables.](#)

External Resources

- [LCA Tutorials](#)
- [TEA Tutorials](#)
- [Techtest Tutorials](#)
- [More Resources](#)

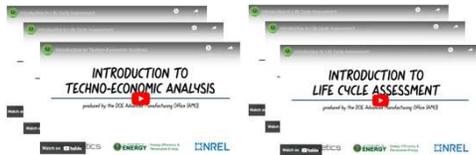


When provided with cost, energy, and emissions data for new and benchmark technologies, TECHTEST will generate summary tables and visualizations detailing the potential benefits and drawbacks resulting from deployment of the new technology. The tool has been developed to help clearly demonstrate the benefits of an emerging technology to potential investors as well as to state and federal funding agencies.



While working with TECHTEST, you will input data for a new process or product as well as for its analogous industry benchmark technology. TECHTEST will then generate comparative insights about the economic and environmental impacts of both technologies.

If you are not familiar with LCA or TEA fundamentals, please refer to our other videos:

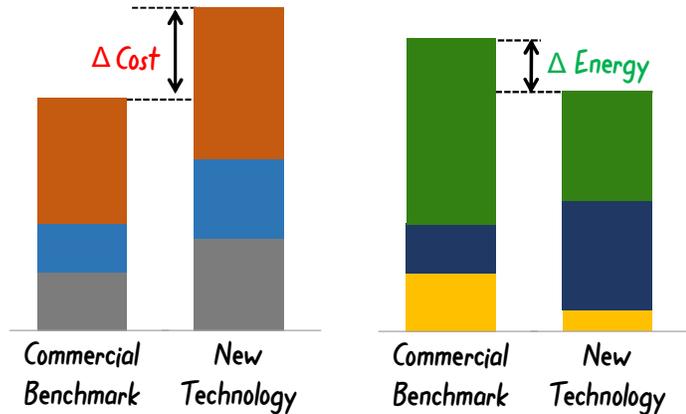


Open up the tool and follow along!

Commercial Benchmark



New Process or Product



Note that if you are not yet familiar with Life Cycle Assessment and Techno-Economic Analysis fundamentals, please refer to our other tutorial videos in this series. Also, please note that TECHTEST only examines the Global Warming Potential impacts of the new product or process and does not incorporate other environmental factors. Before continuing, we encourage you to open up the tool itself and follow along to get a hands-on understanding of its required inputs and overall functionality.

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- [TEA Tutorials](#)
- [TECHTEST Tutorial](#)
- [More Resources](#)

Navigation Bar:

TECHTEST Landing Page	Full Entry Home Page	Rapid Data Entry Home Page	Project Basics & Benchmarks	Market	Functional Unit	Raw Materials	Manufacturing Energy	Use Phase Energy	CapEx	OpEx	Unit Conversion	Grid Mix Customization	Summary Tables	Results Dashboard
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Backend data tables

Tutorial videos

The TECHTEST tool starts with a few introductory tabs that contain helpful information. The TECHTEST Landing Page contains links to tutorial videos, and back-end data tables.

Method 1. Full Analytical Approach

This method generates results from scratch, starting with source data. This is the recommended method for most users who are starting from scratch. If you are beginning with a complete cost, energy, and emissions analysis in another format and simply need to "port" data into the IPA template, you can consider the Rapid Data Entry Approach.

To estimate the potential cost & environmental impacts of a new technology, complete all green input tabs. You will input data for both the new technology (being developed in this project) and for the commercial benchmark technology (that you will be comparing to). Follow the instructions provided to enter data in cells that are shaded blue (text or numeric entry) or gold (dropdown menu selection). Be as complete and specific as possible in your data entries. Document assumptions, references, calculations, and estimation methods used.

It works best to complete tabs in order from left to right - but it is OK to fill them out of order, if needed. If filling tabs out-of-order, follow instructions carefully to enter certain data points in earlier tabs as needed, rather than over-writing formulae in the sheet. This will avoid problems with duplicate data entries, cell reference errors, and named variables. Data should be entered ONLY in the blue and gold cells.

Data input tabs for the Full Analytical Approach are linked below:

1	Project Basics & Benchmarks (Tier 1)
2	Market (Tier 2)
3	Functional Unit (Tier 2)
4	Raw Materials (Including: Embodied Energy, Emissions, and Costs (Tier 2))
5	Manufacturing Energy (Manufacturing Phase Energy & Emissions (Tier 2))
6	Use Phase Energy (Energy and Emissions (Tier 2))
7	Grid Mix
8	CapEx (Tier 2)
9	OpEx (Tier 2)

As data fields in the input tabs are filled, summary result tables and plots will automatically start to appear in the two results output tabs (shaded navy blue). In these tabs, the new technology will be compared head-to-head with the commercial benchmark technology on an energy and cost basis. After completing all of the Input tabs, you can scroll the Summary Results Output tabs to view the summary in table and graphical formats.

Data input tabs for the Full Analytical Approach

TECHTEST Landing Page	Full Entry Home Page	Rapid Data Entry Home Page	Project Basics & Benchmarks	Market	Functional Unit	Raw Materials	Manufacturing Energy	Use Phase Energy	CapEx	OpEx	Unit Conversion	Grid Mix Customization	Summary Tables	Results Dashboard
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On the Full Entry Home Page tab, you will find a list of data input tabs for the Full Analytical Approach, which we'll be going through today.

Streamlines the process for users who have already completed their analysis in another format

Method 2. Rapid Data Entry Approach

The Rapid Data Entry Approach, which requires high-level data entries only, is intended for users who have already completed an analysis in another format, but wish to quickly "port" results into TECHTEST to generate results tables and dashboards in the IPA format.

It is also possible to mix-and-match the two approaches by partially completing the Rapid Data Entry sheet using available data, then making more detailed calculations in appropriate tabs of the Full Analytical Approach to estimate missing data. Results from Full Analytical tabs can be copied and pasted (as values) into appropriate cells of the Rapid Data Entry Approach to populate a complete dataset.

To estimate the potential cost & environmental impacts of a new technology, first complete the two light-green Tier 1 data input tabs, also used in Method 1 (Project Basics and Benchmarks, and Performance Metrics). Then, skip ahead to the orange "Rapid Data Input" tab for Method 2. In this sheet, you will input high-level cost, energy, and emissions data for both the new technology (being developed in this project) and for the commercial benchmark technology (that you will be comparing to). Follow the instructions provided to enter data in cells that are shaded blue. Be as complete and specific as possible in your data entries. Document assumptions, references, calculations, and estimation methods used.

Data input tabs for the Rapid Data Entry Method are linked below:

- 1 [Project Basics and Benchmarks \(Tier 1\)](#)
- 2 [Rapid Data Input Sheet for Method 2 \(Tier 2\)](#)

As data fields in the input tabs are filled, summary result tables and plots will automatically start to appear in the Method 2 results output tabs (shaded deep red). In these tabs, the new technology will be compared head-to-head with the commercial benchmark technology on an energy and cost basis - in the same format as Method 1.

Notes that the accuracy of the generated tables and plots depends on the completeness of data in the Input tabs. After reviewing, you may wish to go back to the input tabs to add further detail and improve the quality of the results.

The results summary output tabs for the Rapid Data Entry Approach are linked below:

- 1 [Results Summary Tables \(Method 2\)](#)
- 2 [Graphical Results Dashboard \(Method 2\)](#)

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There's also a Rapid Data Entry Home Page, which streamlines the process for users who have already completed their analysis in another format and are using TECHTEST to quickly generate results tables and visualizations.

Method 1. Full Analytical Approach

This method generates results from scratch, starting with source data. This is the recommended method for most users who are starting from scratch. If you are beginning with a complete cost, energy, and emissions analysis in another format and simply need to "port" data into the IPA template, you can consider the Rapid Data Entry Approach.

To estimate the potential cost & environmental impacts of a new technology, complete all green input tabs. You will input data for both the new technology (being developed in this project) and for the commercial benchmark technology (that you will be comparing to). Follow the instructions provided to enter data in cells that are shaded blue (text or numeric entry) or gold (dropdown menu selection). Be as complete and specific as possible in your data entries. Document assumptions, references, calculations, and estimation methods used.

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Data input tabs for the Full Analytical Approach are linked below:

1	Project Basics & Benchmarks (Tier 1)
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7	Grid Mix
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9	OpEx (Tier 2)

As data fields in the input tabs are filled, summary result tables and plots will automatically start to appear in the two results output tabs (shaded navy blue). In these tabs, the new technology will be compared head-to-head with the benchmark technology on an energy and cost basis. After completing all of the input tabs, you can scroll

Blue Cells: User input - text or numerical

Yellow Cells: User input - select from dropdown

Purple Cells: Default data based on EIA sector averages or standard assumptions (can be user modified if more specific data are available)

Other Cells: Not intended for editing

Data Inputs Required:

Project Basics

Life Cycle Impacts

Economic Considerations

TECHTEST Landing Page	Full Entry Home Page	Rapid Data Entry Home Page	Project Basics & Benchmarks	Market	Functional Unit	Raw Materials	Manufacturing Energy	Use Phase Energy	CapEx	OpEx	Unit Conversion	Grid Mix Customization	Summary Tables	Results Dashboard
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We'll be focusing on the Full Analytical Approach in this video. Throughout the tool, you will see blue, yellow, and purple cells: blue cells take text or numerical user input data; yellow cells will have you choose from a dropdown menu of options; and purple cells are filled with default data based on sector averages or standard assumptions (though these can be modified if more specific data are available). In this Full Analytical Approach, the data inputs required to generate results by TECHTEST fall into three categories: Project Basics, Life Cycle Impacts and Economic Considerations.

We'll start with a general overview of what's contained in each of these sections.

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Project & Technology Description

Project Title	Waste Heat Recovery Cooling in Beverage Manufacturing
Lead Organization	Hypothetical Organization
Collaborative Partner(s)	Staff
Principal Investigator Name	John Doe
Principal Investigator Organization	Hypothetical National Laboratory
AMO Technology Manager	Jane Doe
Project Start	January-23
Project End	January-25
Funding Mechanism	R&D Project

Technology Benchmarking

Define the generic market-end use product. If the new technology, commercial benchmark, other competing technologies produce different products that serve the same function and would be used in the same market, the generic market end-use product should be defined generally enough to encompass these different products or variations. For example, a Market End Use Product could be "automotive high strength steel" rather than the more specific "HSLA 350 steel produced by XYZ process." Defining a product and market that is too-specific may overly restrict the impact analysis.

Generic Market End-Use Product*:

is the end-use products of all competing technologies that serve the same function. Specific differences in the end product are captured in the Specific Product or Service field.

Definition	Specific Product or Service		
Use Phase	CapEx	OpEx	Unit Cost
Energy			

TECHTEST Landing Page **Project Basics & Benchmarks** **Market** **Functional Unit** **Grid Mix Customization** Results Dashboard

There are four tabs that fall into the Project Basics category. These tabs help the user get started by describing the associated industry and fundamentals of the project.

Definitions of Competing Technologies and Products		Technology Definition	Specific Product or Application	Technology Status										
		<i>Define the technology.</i>	<i>Identify the end-use products and/or key applications for this technology, noting any differences.</i>	<i>Is this technology a current typical technology, a state-of-the-art technology, or an emerging technology?</i>										
	New Technology (developed in this project)	Waste Heat Recovery (Heat Pump)	Cooled Waste Water	Typical Technology										
	Commercial Benchmark Technology	Evaporative Condenser	Cooled Waste Water	Typical Technology										
	Other Competing Technologies (list relevant technologies, separating by commas)													
Energy, Emissions & Cost Impact Drivers		Note: This section examines emissions over the <u>entire lifecycle</u>.												
Energy & Emissions Impacts by Life Cycle Phase	In your opinion, would this technology be likely to impact the energy and/or emissions associated with ...	Yes/No	Mechanism <i>(Explain why this technology would be likely to have an impact.)</i>											
	... raw materials used in the manufacturing process?	No												
	... manufacturing the end-use product?	Yes	Higher energy efficiency, no cooling water needed											
	... using, transporting, or disposing of the end-use product?	No												
Manufacturing Cost Impacts by Cost Component	In your opinion, would this technology be likely to impact the manufacturing costs associated with ...	Yes/No	Mechanism											
	... capital equipment?	No												
	... raw materials used in manufacturing?	No												
	... energy used in manufacturing?	No												
	... manufacturing labor?	No												
Impacts by Sector <i>For each sector that would be impacted by the new technology, briefly describe the <u>mechanisms</u> of potential impacts. (Assume successful commercialization and adoption.)</i>	In your opinion, would this technology be likely to impact the following sectors (energy, emissions, or cost)?	Yes/No	Mechanism											
	Mining	No												
	Manufacturing	Yes	Used to save energy in beverage manufacturing											
	Transportation	No												
	Energy Generation (utility scale)	No												
	Energy Generation (device scale)	No												
TECHTEST Landing Page	Full Entry Home Page	Rapid Data Entry Home Page	Project Basics & Benchmarks	Market	Functional Unit	Raw Materials	Manufacturing Energy	Use Phase Energy	CapEx	OpEx	Unit Conversion	Grid Mix Customization	Summary Tables	Results Dashboard

In the Project Basics & Benchmarks tab, the user identifies where energy, emissions, and cost improvements may occur with respect to the new technology.

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Market Size

Quantify the total size of the end-use product market. Provide calculations and references at the bottom of the sheet. The end-use product should be defined in the Benchmarking section of the Project Basics tab.

Annual U.S. Production of End-use Product: Million Gallons of Cooled Waste Water per year
(all U.S. production, all facilities) (units)

If the new technology will NOT be deployed in an existing market, or there is not yet any U.S. production of the end-use product, explain below.

Comments:

Market Breakdown

Estimate the percent market share for the new technology, the commercial benchmark, and other competing technologies:

- In the "Current Conditions" column, estimate the market breakdown based on the current U.S. market.
- In the "Overnight Adoption" column, estimate the market breakdown in a hypothetical "overnight adoption" marketplace where the new technology is fully deployed, but all other market conditions remain the same as the current U.S. market.

The total market share in each column should sum to 100%.

Technology*	Product / Application*:	Pre-Deployment	Full Deployment
		Market Share (%):	Market Share (%): "Target Potential Market at Full Deployment"

TECHTEST Landing Page | Full Entry Home Page | Rapid Data Entry Home Page | Project Basics & Benchmarks | **Market** | Functional Unit | Raw Materials | Manufacturing Energy | Use Phase Energy | CapEx | OpEx | Unit Conversion | Grid Mix Customization | Summary Tables | Results Dashboard

The Market tab collects information on the projected market size...

Annual U.S. Production of End-use Product: Million Gallons of Cooled Waste Water per year
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The total market share in each column should sum to 100%.

Technology*	Product / Application*	Pre-Deployment	Full Deployment
		Market Share (%): Current Conditions	Market Share (%): "Target Potential Market at Full Deployment" Hypothetical Scenario
New Technology: Waste Heat Recovery (Heat Pump)	Cooled Waste Water	0%	100%
Commercial Benchmark: Evaporative Condenser	Cooled Waste Water	100%	0%
Other Competing Technologies:	0	0	
Sum:		100%	100%

*Note that the technology and product definitions are imported from the Benchmarking section of the "Project Basics" tab. If any edits to these definitions are needed, please modify the definitions in that tab.

TECHTEST Landing Page	Full Entry Home Page	Rapid Data Entry Home Page	Project Basics & Benchmarks	Market	Functional Unit	Raw Materials	Manufacturing Energy	Use Phase Energy	CapEx	OpEx	Unit Conversion	Grid Mix Customization	Summary Tables	Results Dashboard
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...and market share of the two technologies.

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Functional Units and Reference Quantities

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An explanation of best practices for choosing a functional unit can be found in DOE's "Functional Units" short tutorial video:
[https://www.youtube.com/watch?v=6_5j8kTomD08ab_channel=US Department of Energy](https://www.youtube.com/watch?v=6_5j8kTomD08ab_channel=US%20DepartmentofEnergy)

A Functional Unit defines the quantity of a product or product system based on the performance it delivers in its end-use application. The purpose of defining a performance-based functional unit is to facilitate accurate comparisons (of environmental or cost metrics) for disparate products or systems that serve the same final function. The functional unit can be used to objectively compare the new technology to the commercial benchmark technology. The process can be broken down into two steps:

Describing the final function for the technology and defining the functional unit.

	Examples
-If the technology is a production method , you can define the functional unit based on a quantity of product that the process creates. For Example: A steel smelting process could be defined based on its ability to produce 1 kg of automotive steel.	The total volume of catalyst required to produce 1 ton of ethylene. The mass of steel required to produce an automotive B-pillar for an average mid-size sedan.
-If the technology is a product , you can define the functional unit based on a quantitative measure of the intended function of the product. For Example: A light source could be defined based on its ability to produce 1,000 lumens of brightness for 1,000 hours.	All light bulbs required to produce 1,000 lumens over 100,000 hours. All shipping pallets required to deliver 100,000 lbs of product load at a dynamic load rating of 5,000 lbs.

Step 1: Based on the functional unit, specify a reference quantity for the New Technology that can be compared to an equivalent reference quantity for the Commercial Benchmark Technology.

Use the functional unit to specify a **production reference quantity for the new technology**, as shown in the examples below.

Functional Unit Based Reference Quantity for the New Technology: Million Gallons of Cooled Waste Water for New Technology

Value Unit of Product

Examples: 80 kg of new ethylene catalyst
1,000,000 lumen-hours produced by a new LED bulb
9 kg of dual-phase high strength steel
18 recycled polymer pallet shipping pallets in novel design

Finally, specify the performance-equivalent production reference quantity for the commercial benchmark technology, as shown in the examples below. Note that this value may be the same or different from the reference quantity for the new technology. It depends on how you've defined your functional unit, and whether the new technology will serve as a drop-in replacement for the benchmark technology.

Performance Equivalent Reference Quantity for the Commercial Benchmark: Million Gallons of Cooled Waste Water for Commercial Benchmark Technology

Value Unit of Product

Examples: 90 kg of conventional ethylene catalyst
1,000,000 lumen-hours produced by a current typical lightbulb
kg of conventional mild steel

TECHTEST Landing Page | Full Entry Home Page | Rapid Data Entry Home Page | Project Basics & Benchmarks | Market | **Functional Units** | Raw Materials | Manufacturing Energy | Use Phase Energy | CapEx | OpEx | Unit Conversion | Grid Mix Customization | Summary Tables | Results Dashboard

The Functional Unit tab specifies the reference quantity for the new technology as well as a performance-equivalent reference quantity for the benchmark technology. The reference quantity specifies the amount of product delivered based on the performance of each technology.

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Grid Mix Customization

On this page, you can customize the grid mix used in the calculation of electricity generation emissions in the TECHTEST tool. The specific Grid Mix is an estimation of the percentage of various energy sources used to create powerline electricity. The 2022 current US grid mix is the default. A Moderate and Net Zero scenario are also included, and can be selected using the "Choose Grid Mix" dropdown menu.

Choose Grid Mix (select from dropdown) **2022 Default**

Blue Cells: User input - text or numerical
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Other Cells: Not intended for editing

Electricity Generation Technology		Fraction of Total	Life-Cycle Electricity generation emissions (lb CO2-eq/MMBtu electricity generated) based on IPCC data	Default CO2-eq/MMBtu data	
Electricity Generation Technologies	Fossil Fuels	Coal	21.9%	234.36	234.36
		Petroleum	0.5%	177.08	177.08
		Natural Gas	38.3%	130.62	130.62
		Other Gases	0.3%	127.13	127.13
	Renewables	Nuclear	18.9%	7.76	7.76
		Hydropower	6.3%	15.52	15.52
		Biomass - Wood	0.9%	148.75	148.75
		Biomass - Waste	0.5%	148.75	148.75
		Geothermal	0.4%	24.58	24.58
		Solar	2.8%	31.04	31.04
Wind	9.2%	7.11	7.11		
		100.0%			
Weighted average emissions for U.S. electricity generation:			108.6 lb CO2-e		

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Electricity Generation Technology		Fraction of Total	Life-Cycle Electricity generation emissions (lb CO2-eq/MMBtu electricity generated) based on IPCC data
Electricity Generation Technologies	Fossil Fuels	Coal	234.36
		Petroleum	177.08
		Natural Gas	130.62
		Other Gases	127.13
	Renewables	Nuclear	7.76
		Hydropower	15.52
		Biomass - Wood	148.75
		Biomass - Waste	148.75
		Geothermal	24.58
		Solar	31.04
Wind	7.11		
		0.0%	
Weighted average emissions for U.S. electricity generation:			0.0 lb CO2-e

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TECHTEST Landing Page | Full Entry Home Page | Rapid Data Entry Home Page | **Project Basics & Benchmarks** | Market | Functional Unit | Raw Materials | Manufacturing Energy | Use Phase Energy | CapEx | OpEx | Unit Conversion | **Grid Mix Customization** | Summary Tables | Results Dashboard

Additionally, further to the right in the tab menu is the Grid Mix Customization tab, which allows you to choose between various default scenarios for the mix of electricity generation technologies...

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Electricity Generation Technology		Fraction of Total	Life-Cycle Electricity generation emissions (lb CO2-eq/MMBtu electricity generated) based on IPCC data	Default CO2-eq/MMBtu data	
Electricity Generation Technologies	Fossil Fuels	Coal	21.9%	234.36	234.36
		Petroleum	0.5%	177.08	177.08
		Natural Gas	38.3%	130.62	130.62
		Other Gases	0.3%	127.13	127.13
	Renewables	Nuclear	18.9%	7.76	7.76
		Hydropower	6.3%	15.52	15.52
		Biomass - Wood	0.9%	148.75	148.75
		Biomass - Waste	0.5%	148.75	148.75
		Geothermal	0.4%	24.58	24.58
		Solar	2.8%	31.04	31.04
Wind	9.2%	7.11	7.11		
		100.0%			
Weighted average emissions for U.S. electricity generation:			108.6 lb CO2-e		

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Electricity Generation Technology		Fraction of Total	Life-Cycle Electricity generation emissions (lb CO2-eq/MMBtu electricity generated) based on IPCC data
Electricity Generation Technologies	Fossil Fuels	Coal	234.36
		Petroleum	177.08
		Natural Gas	130.62
		Other Gases	127.13
	Renewables	Nuclear	7.76
		Hydropower	15.52
		Biomass - Wood	148.75
		Biomass - Waste	148.75
		Geothermal	24.58
		Solar	31.04
Wind	7.11		
		0.0%	
Weighted average emissions for U.S. electricity generation:			0.0 lb CO2-e

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TECHTEST Landing Page	Full Entry Home Page	Rapid Data Entry Home Page	Project Basics & Benchmarks	Market	Functional Unit	Raw Materials	Manufacturing Energy	Use Phase Energy	CapEx	OpEx	Unit Conversion	Grid Mix Customization	Summary Tables	Results Dashboard
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...or input a custom mix of fossil-fuel and renewable sources.

Raw Material Embodied Energy, Emissions, and Costs

In this tab, you will estimate the embodied energy, embodied carbon, and cost for raw material inputs to manufacturing, for the New Technology (left) and for the Commercial Benchmark (right). Note that the technology definitions and product definitions are imported by default from the Benchmarking section of the "Project Basics" tab, and reference quantities are imported from the "Functional Unit" tab. If any edits to these values are needed, please modify in those tabs to ensure changes are carried through entire analysis.

New Technology (at Industrial Scale)		Commercial Benchmark	
Technology Name	Waste Heat Recovery (Heat Pump)	Technology Name	Chlorine Condenser
Specific Product	Cooled Waste Water	Specific Product	Cooled Waste Water
Reference Quantity	2.00 Million Gallons	Reference Quantity	2.00 Million Gallons
(Quantity)	(Units)	(Quantity)	(Units)

List all significant input materials in the table below, considering the reference quantity specified in the prior tab (and shown above), specify for each input material the amount required to produce the reference quantity, as well as the specific embodied energy, specific embodied carbon*, and specific cost for each material. Follow the same process for the new technology (left) and commercial benchmark technology (right) to facilitate comparisons.

Embodied energy and carbon for input materials may conveniently be estimated using NREL's Materials Flow Through Industry (MFTI) tool (using the exact materials if available, or using similar "proxy" materials as an estimate). Indicate the specific MFI material names used for estimates (or other sources and assumptions) in the "References, Notes, and Assumptions" section below. The tool tab linked below can be used to easily extract embodied energy and carbon values from MFI results output. MFI embodied energy and carbon results can then be pasted as values in the Specific Embodied Energy column.

[Calculator Tool: Extracting Embodied Energy & Carbon from MFI](#)

New Technology - Raw Material Inputs							Commercial Benchmark - Raw Material Inputs										
Material Inputs (lbs)	Amount of Material (to produce reference quantity)	unit	Specific Embodied Energy (Btu/unit) (for this material)	Specific Embodied carbon (lbs CO2-eq/unit) (for this material)	Specific cost (\$/unit) (for this material)	Embodied Energy (MMBtu) (per reference quantity of product)	Embodied carbon (lbs CO2-eq) (per reference quantity of product)	cost (\$)	Material Inputs (lbs)	Amount of Material (to produce reference quantity)	unit	Specific Embodied Energy (Btu/unit) (for this material)	Specific Embodied carbon (CO2-eq/unit) (for this material)	Specific cost (\$/unit) (for this material)	Embodied Energy (MMBtu) (per reference quantity of product)	Embodied carbon (lbs CO2-eq) (per reference quantity of product)	cost (\$)
Lubrication (to Run Fans)	2.340	kg	80.564	4.7	\$4.00	0.2 MMBtu	11 lbs CO2-e	\$14	city water supply to evaporative condensers	17.010	gallons	17.9394	0.002904	\$0.0020	0.3 MMBtu	43 lbs CO2-e	\$34
Copper	0.367303562	kg	39808.3	2.6		0.0 MMBtu	1 lbs CO2-e	\$0	Biocide chemical addition to cooling loop for micro mitigation	3.322326031	gallons	119.0610231	0.0132	\$19.09	0.0 MMBtu	0.044 lbs CO2-e	\$63
Elastomer	0.160926863	kg	94781.7	5.5		0.0 MMBtu	1 lbs CO2-e	\$0	Steel low Alloy	0.317497941	kg	19051.1	1.4		0.0 MMBtu	0 lbs CO2-e	\$0
HDPE	0.005017808	kg	69190.6	1.6		0.0 MMBtu	0 lbs CO2-e	\$0	Stainless Steel	0.349464668	kg	93741.394	6.2		0.0 MMBtu	2 lbs CO2-e	\$0
Low alloyed steel	0.321139726	kg	18051.1	1.4		0.0 MMBtu	0 lbs CO2-e	\$0	Aluminum	0.398757345	kg	146912.1	9.2		0.1 MMBtu	4 lbs CO2-e	\$0
Lubricating Oil (Manufacturing)	0.027996284	kg	80564.4	4.7		0.0 MMBtu	0 lbs CO2-e	\$0	Bricks	0.346260477	Bricks	2842.46	0.2		0.0 MMBtu	0 lbs CO2-e	\$0
PVC	0.016056986	kg	73171.5	2.4		0.0 MMBtu	0 lbs CO2-e	\$0	Methacrylate	0.288178188	kg	110079.8148	5.9		0.0 MMBtu	2 lbs CO2-e	\$0
Reinforced Steel	1.304630137	kg	18051.1	1.4		0.0 MMBtu	2 lbs CO2-e	\$0	Polyurethane	0.025744085	kg	68337.822	3.8		0.0 MMBtu	0 lbs CO2-e	\$0
									PVC	0.495184723	kg	73171.704	3.1		0.0 MMBtu	2 lbs CO2-e	\$0
Total embodied energy and cost for input materials:									Total embodied energy and cost for input materials:								
0.3 MMBtu									0.5 MMBtu								
15 lbs CO2-e									52 lbs CO2-e								
\$14									\$37								

*The IPA team defines "embodied carbon" for a material as the 10-year global Warming Potential (GWP10) data for GWP and combustion emissions factors are available in the Reference Data tab linked below.
[Reference Data: 100-Year GWP & Combustion Emission Factors](#)

Raw Materials

Manufacturing Energy

Use Phase Energy

Moving on, the Life Cycle Impacts category, is composed of three tabs make up the bulk of the environmental and economic assessments of the technologies.

Raw Material Embodied Energy, Emissions, and Costs

In this tab, you will estimate the embodied energy, embodied carbon, and cost for raw material inputs to manufacturing, for the New Technology (left) and for the commercial Benchmark (right). Note that the technology definitions and product definitions are imported by default from the Benchmarking section of the "Project Basics" tab, and reference quantities are imported from the "Functional Unit" tab. If any edits to these values are needed, please modify in those tabs to ensure changes are carried through entire analysis.

New Technology (at industrial Scale)

Technology Name: Waste Heat Recovery (Heat Pump)
 Specific Product: Cooled Waste Water
 Reference Quantity: 2.00 Million Gallons
 (quantity) (units)

Commercial Benchmark

Technology Name: Evaporative Condenser
 Specific Product: Cooled Waste Water
 Reference Quantity: 2.00 Million Gallons
 (quantity) (units)

List all significant input materials in the table below. Considering the reference quantity specified in the prior tab (and shown above), specify for each input material the amount required to produce the reference quantity, as well as the specific embodied energy, specific embodied carbon, and specific cost for each material. Follow the same process for the new technology (left) and commercial benchmark technology (right) to facilitate comparisons.

Embodied energy and carbon for input materials may conveniently be estimated using NREL's Materials Flow Through Industry (MFI) tool (using the exact materials if available, or using similar "proxy" materials as an estimate). Indicate the specific MFI material names used for estimates (or other sources and assumptions) in the "References, Notes, and Assumptions" section below. The tool tab linked below can be used to easily extract embodied energy and carbon values from MFI results output. MFI embodied energy and carbon results can then be pasted as values in the Specific Embodied Energy column.

[Calculator Tool: Extracting Embodied Energy & Carbon from MFI](#)

New Technology - Raw Material Inputs

Material Inputs (list)	Amount of Material (to produce reference quantity)	unit	Specific Embodied Energy (BTU/unit) (for this material)	Specific Embodied carbon (lbs CO ₂ -eq/unit) (for this material)	Specific cost (\$/unit) (for this material)	Embodied Energy (MMBTu) (per reference quantity of product)	Embodied carbon (lbs CO ₂ -e) (per reference quantity of product)	Cost (\$) (per reference quantity of product)
Lubrication (to run Fans)	2.340	kg	80,564	4.7	\$6.00	0.2 MMBTu	11 lbs CO ₂ -e	\$14
Copper	0.367303562	kg	39808.3	2.6		0.0 MMBTu	1 lbs CO ₂ -e	\$0
Elastomer	0.160569863	kg	94781.7	5.5		0.0 MMBTu	1 lbs CO ₂ -e	\$0
HDPE	0.005017808	kg	69190.6	1.6		0.0 MMBTu	0 lbs CO ₂ -e	\$0
Low alloyed steel	0.321139726	kg	19051.1	1.4		0.0 MMBTu	0 lbs CO ₂ -e	\$0
Lubricating Oil (Manufacturing)	0.027096164	kg	80564.4	4.7		0.0 MMBTu	0 lbs CO ₂ -e	\$0
PVC	0.016056986	kg	73171.5	2.4		0.0 MMBTu	0 lbs CO ₂ -e	\$0
Reinforced Steel	1.304630137	kg	19051.1	1.4		0.0 MMBTu	2 lbs CO ₂ -e	\$0
Total embodied energy and cost for input materials:						0.3 MMBTu	15 lbs CO ₂ -e	\$14

Commercial Benchmark - Raw Material Inputs

Material Inputs (list)	Amount of Material (to produce reference quantity)	unit	Specific Embodied Energy (BTU/unit) (for this material)	Specific Embodied carbon (CO ₂ -eq/unit) (for this material)
City water supply to evaporative condensers	17,010	gallons	17,9394	0.0025
Biocide chemical additon to cooling loop for micro mitigation	3.322326031	gallons	119,5610231	0.01
Steel low Alloy	0.317497841	kg	19051.1	
Stainless Steel	0.349464668	kg	53741.394	
Aluminium	0.398757315	kg	146912.1	
Bricks	0.346265477	Bricks	2843.46	
Methacrylate	0.288178188	kg	110079.8148	
Polyurethane	0.025744085	kg	68337.822	
PVC	0.495184723	kg	73171.704	
Total embodied energy and cost for				

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Project Basics & Benchmarks

Market

Functional Unit

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The Raw Materials tab incorporates data on the materials required to produce the identified reference quantity for both technologies. This data includes, embodied energy, CO2 and cost.

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Manufacturing Energy, Emissions, and Energy Costs

Estimate onsite energy consumption (in the blue input cells) by energy/fuel type. Energy consumption totals should correspond to the reference quantity of finished product, as provided in the Functional Unit tab. Follow the same process for the new technology (left) and commercial benchmark technology (right) to facilitate comparisons. Default data are provided for energy prices, GWP, and source-to-site ratios (in the violet cells). These are based on industrial sector averages (see Summary Ref Tables tab) and can be user-adjusted from the default values for greater accuracy, if better estimates are available. IPCC AR5 values for 100-Year Global Warming Potential (GWP) are used to estimate the emissions associated with energy consumption. See the GWP & Composition Data tab (linked below) for source data and assumptions.

Blue Cells: User input - text or numerical
Yellow Cells: User input - select from dropdown
Purple Cells: Default data based on EIA sector averages or standard assumptions (can be user modified if more specific data are available)
Other Cells: Not intended for editing

New Technology (at Industrial Scale)

Technology Name: Waste Heat Recovery (Heat Pump)
 Specific Product: Cooled Waste Water
 Reference Quantity: 2.00 Million Gallons (quantity)

Commercial Benchmark

Technology Name: Evaporative Condenser
 Specific Product: Cooled Waste Water
 Reference Quantity: 2.00 Million Gallons (quantity)

New Technology - Energy Consumption & Cost Data (to produce reference quantity)

Fuel or Energy Type	Energy Source (Dropdowns available for Petroleum, Coal, and Renewable)	Onsite Energy consumption* (MMBtu)	Specific Price (\$/MMBtu)	Specific 100-yr GWP (lb CO2-eq/MMBtu)	Source-to-Site Ratio (electricity and steam only)	Primary Energy consumption, including offsite losses (MMBtu)	Energy cost (\$)	GWP Emissions (lb CO2-eq)
Electricity	Electricity	0.0048	\$21.04	108.8	2.86	0.01	\$0.10	0.5 lb CO2-e
Petroleum	Diesel & distillate fuel oil		\$18.34	172.926	1.00			
Coal	Anthracite		\$6.99	229.8	1.00			
Natural Gas	Natural Gas	0.0133	\$5.79	130.6	1.00	0.01	\$0.06	1.7 lb CO2-e
Renewable	Wood Biomass		\$2.89	264.9	1.00			
Steam	Steam and hot water**		\$4.70	146.4	1.20			
Custom input I								
Custom input II								
Custom input III	Petroleum coke		\$4.31	227.4	1.00			
						0.03	\$0.18	2.3 lb CO2-e

Commercial Benchmark - Energy Consumption & Cost Data (to produce reference quantity)

Fuel or Energy Type	Energy Source (Dropdowns available for Petroleum, Coal, and Renewable)	Onsite Energy consumption* (MMBtu)	Specific Price (\$/MMBtu)	Specific 100-yr GWP (lb CO2-eq/MMBtu)	Source-to-Site Ratio (electricity and steam only)	Primary Energy consumption, including offsite losses (MMBtu)	Energy cost (\$)	GWP Emissions (lb CO2-eq)
Electricity	Electricity		\$21.04	108.6	2.86	1.06	\$7.81	40.3 lb CO2-e
Petroleum	Diesel & distillate fuel oil		\$18.34	172.926	1.00			
Coal	Anthracite		\$6.99	229.8	1.00			
Natural Gas	Natural Gas	0.01	\$5.79	130.6	1.00	0.01	\$0.08	1.7 lb CO2-e
Renewable	Wood Biomass		\$2.89	264.9	1.00			
Steam	Steam and hot water**		\$4.70	146.4	1.20			
Custom input I								
Custom input II								
Custom input III	Liquid Petroleum Gas		\$12.22	146.9	1.00			
						1.07	\$7.89	42.1 lb CO2-e

Manufacturing Process Emissions (if applicable)

If there are process emissions associated with either the new technology or commercial benchmark technology, list the emissions and associated 100-year GWP below. Do not include any emissions associated with combustion of fuels (already captured above). If there are no significant process emissions, leave this section blank.

New Technology - Process Emissions (to produce reference quantity)

Emission Type (chemical name or acronym)	Amount emitted (lb)	100-Year GWP*	Suggested 100-Year GWP	Embodied carbon (lb CO2-eq)
R-334a	0.09	1,300		64 lbs CO2-e
Total:				64 lbs CO2-e

Commercial Benchmark - Process Emissions (to produce reference quantity)

Emission Type (chemical name or acronym)	Amount emitted (lb)	100-Year GWP*	Suggested 100-Year GWP	Embodied carbon (lb CO2-eq)
				0 lbs CO2-e
Total:				0 lbs CO2-e

* Use IPCC AR5 values for 100-Year Global Warming Potential (GWP). See the GWP Data tab (linked below) for excerpted GWP values for the most common emissions types, and a link to the full IPCC report for a complete list.
[References Data Tables, Global Warming Potential](#)

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The Manufacturing Energy tab calculates the energy required to manufacture the reference quantity...

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Manufacturing Energy, Emissions, and Energy Costs
 Estimate onsite energy consumption (in the blue input cells) by energy/fuel type. Energy consumption totals should correspond to the reference quantity of finished product, as provided in the Functional Unit tab. Follow the same process for the new technology (left) and commercial benchmark technology (right) to facilitate comparisons. Default data are provided for energy prices, GWP, and source-to-site ratios (in the violet cells). These are based on industrial sector averages (see Summary Ref Tables tab) and can be user-adjusted from the default values for greater accuracy, if better estimates are available. IPCC AR5 values for 100-Year Global Warming Potential (GWP) are used to estimate the emissions associated with energy consumption. See the GWP & Combustion Data tab (linked below) for source data and assumptions.

Blue Cells: User input - text or numerical
Yellow Cells: User input - select from dropdown
Purple Cells: Default data based on EIA sector averages or standard assumptions (can be user modified if more specific data are available)
Other Cells: Not intended for editing

New Technology (at Industrial Scale)							Commercial Benchmark						
Technology Name	Waste Heat Recovery (Heat Pump)						Technology Name	Evaporative Condenser					
Specific Product	Cooled Waste Water						Specific Product	Cooled Waste Water					
Reference Quantity	2.00	Million Gallons					2.00	Million Gallons					
	(quantity)	(units)					(quantity)	(units)					

New Technology - Energy Consumption & Cost Data (to produce reference quantity)

Fuel or Energy Type	Energy Source (Dropdowns available for Petroleum, Coal, and Renewable)	Onsite Energy consumption* (MMBtu)	Specific Price (\$/MMBtu)	Specific 100-yr GWP (lb CO2-eq / MMBtu)	Source-to-Site Ratio (electricity and steam only)	Primary Energy consumption, including offsite losses (MMBtu)	Energy cost (\$)	GWP Emissions (lb CO2-eq)
Electricity	Electricity	0.0048 MMBtu	\$21.04	108.6	2.86	0.01 MMBtu	\$0.10	0.5 lb CO2-e
Petroleum	Diesel & distillate fuel oil		\$18.34	172.926	1.00			
Coal	Anthracite		\$6.59	229.8	1.00			
Natural Gas	Natural Gas	0.0133 MMBtu	\$5.79	130.6	1.00	0.01 MMBtu	\$0.08	1.7 lb CO2-e
Renewable	Wood Biomass		\$2.89	264.9	1.00			
Steam	Steam and Hot Water**		\$4.70	146.4	1.20			
custom input I								
custom input II								
custom input III	Petroleum coke		\$4.31	227.4	1.00			
						0.03 MMBtu	\$0.18	2.3 lb CO2-e

* link to reference data tab
 ** To avoid double-counting, only enter Steam data in this row if fuel/electricity used to generate the steam is not already included above.

Manufacturing Process Emissions (if applicable)
 If there are process emissions associated with either the new technology or commercial benchmark technology, list the emissions and associated 100-year GWP below. Do not include any emissions associated with combustion of fuels (already captured above).
 If there are no significant process emissions, leave this section blank.

Commercial Benchmark - Energy Consumption & Cost Data (to produce reference quantity)

Fuel or Energy Type	Energy Source (Dropdowns available for Petroleum, Coal, and Renewable)	Onsite Energy consumption* (MMBtu)	Specific Price (\$/MMBtu)	Specific 100-yr GWP (lb CO2-eq / MMBtu)	Source-to-Site Ratio (electricity and steam only)
Electricity	Electricity	0.37 MMBtu	\$21.04	108.6	
Petroleum	Diesel & distillate fuel oil		\$18.34	172.926	
Coal	Anthracite		\$6.59	229.8	
Natural Gas	Natural Gas	0.01 MMBtu	\$5.79	130.6	
Renewable	Wood Biomass		\$2.89	264.9	
Steam	Steam and Hot Water**		\$4.70	146.4	
custom input I					
custom input II	Liquefied Petroleum Gas		\$12.22	146.9	
custom input III					

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...broken down by fuel type.

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Use Phase Energy and Emissions

complete this tab for any technology expected to have an energy impact during final use of the finished product in its end-use sector. Technologies for which the Use Phase is important include energy-consuming devices or systems, energy-producing devices or systems, or material/component inputs to such systems. For example, a lightweight material may provide fuel savings (compared to typical materials) when used in a vehicle; and an energy-efficient device may provide electricity savings (compared to typical devices) when used in a consumer application. If the technology is not expected to have use phase impacts, leave this section blank. Technologies for which the Use Phase is not expected to be important include technologies where the end-use product is identical to that produced using current typical technologies. For example, a new production route for a commodity chemical would not be expected to have use phase impacts because the end-use product (the commodity chemical) is identical.

To evaluate the use phase energy impact, estimate the total U.S. annual energy consumption (for the end-use market impacted by the technology) based on two scenarios:

1. Current Annual Energy consumption
2. Hypothetical Annual Energy consumption, Based on "overnight Replacement" with New Technology

In the "current" scenario, assume the current market size and market conditions. Consider the entire market, including all facilities and manufacturers. In the "overnight Replacement" scenario, assume a hypothetical market in which the new technology was immediately and fully deployed (at its maximum anticipated market share), with the market size and all other market conditions held constant (this is a simplification).

Enter data on an annual basis in the blue cells below, considering the U.S. market and breaking down by sector and energy source. Enter data only into rows for sector(s) and energy sources applicable to the technology. For convenience, sector-average values for GWP and source-to-site ratio (based on EIA and IPCC reference data) are provided in the purple cells. These data may be over-written if more accurate facility- or industry-specific data are available. Provide your references, assumptions, source data, and calculations in the sections at the bottom of this tab.

Default sector data* (can be modified if needed) Data entry** Data entry**

Sector & Energy Type	Energy Source	Specific 100-yr GWP (lb CO2-eq / MMBtu)	Source-to-site Ratio (Btu primary / Btu onsite)	Current Annual U.S. Energy & Emissions - Product Use Phase (based on current technologies in use)				Hypothetical Annual Energy & Emissions - Product Use Phase (based on "overnight replacement" with new technology)					
				Annual Onsite Energy Consumption (MMBtu)	Specific Price (\$/MMBtu)	Annual Primary Energy consumption, including offsite losses (MMBtu)	Annual Associated Cost (\$)	Annual Associated GWP Emissions (tons CO2-e)	Annual Energy consumption (fuel specific units)	Specific Price (\$/MMBtu)	Annual Primary Energy consumption (MMBtu)	Annual Associated Cost (\$)	Annual Associated GWP Emissions (tons CO2-e)
Industrial Sector													
Electricity	Electricity	108.6	2.86	44,577,450.00 MMBtu	\$21.04	127,462,788 MMBtu	\$938,060,095.69	2,420,274 tons CO2-e	108,130,193.05 MMBtu	\$21.04	309,182,690 MMBtu	\$2,275,424,343.79	5,870,765.4 tons CO2-e
Petroleum Look Up	Motor Gasoline	161.8	1.00		\$21.54					\$21.54			
Coal Look Up	Coal Coke	290.5	1.00		\$7.66					\$7.66			
Natural Gas	Natural Gas	130.6	1.00		\$5.79				-222,771,704 MMBtu	\$5.79	-222,771,704 MMBtu	-\$1,290,746,544.34	-14,548,652.1 tons CO2-e
Renewable Look Up	Solar	31.0	1.00		\$14.07					\$14.07			
Steam	Steam and Hot Water*	146.4	1.20		\$4.70					\$4.70			
custom input I													
custom input II													
custom input III													
Transportation Sector													
Electricity	Electricity	108.6	2.86		\$21.04					\$21.04			
Petroleum Look Up	Motor Gasoline	161.8	1.00		\$18.64					\$18.64			
Natural Gas	Natural Gas (pipelines and fuel)	138.2	1.00		\$5.79					\$5.79			
Renewable Fuels	Biomass	169.3	1.00		\$2.89					\$2.89			
custom input I													
custom input II													
custom input III													

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And the Use Phase Energy tab quantifies the expected energy impacts from the product's final use.

phase impacts, leave this section blank. Technologies for which the Use Phase is not expected to be important include technologies where the end-use product is identical to that produced using current typical technologies. For example, a new production route for a commodity chemical would be expected to have use phase impacts because the end-use product (the commodity chemical) is identical.

To evaluate the use phase energy impact, estimate the **total U.S. annual energy consumption** (for the end-use market impacted by the technology) based on two scenarios:

- Current Annual Energy Consumption
- Hypothetical Annual Energy consumption, Based on "Overnight Replacement" with New Technology

In the "current" scenario, assume the current market size and market conditions, consider the entire market, including all facilities and manufacturers. In the "Overnight Replacement" scenario, assume a hypothetical market in which the new technology was immediately and fully deployed (at anticipated market share), with the market size and all other market conditions held constant (this is a simplification).

Enter data on an annual basis in the blue cells below, considering the U.S. market and breaking down by sector and energy source. Enter data only into rows for sector(s) and energy sources applicable to the technology. For convenience, sector-average values for CO₂-to-site ratio (based on EIA and IPCC reference data) are provided in the purple cells. These data may be over-written if more accurate facility- or industry-specific data are available. Provide your references, assumptions, source data, and calculations in the sections at the bottom of this tab.

		Default sector data* (can be modified if needed)		Data entry**		Data entry**										
		Specific 100-yr GWP (lb CO ₂ -eq / MMBtu)	Source-to-Site Ratio (Btu primary / Btu onsite)	Annual Onsite Energy Consumption (MMBtu)	Specific Price (\$/MMBtu)	Annual Primary Energy consumption, including offsite losses (MMBtu)	Annual Associated cost (\$)	Annual Associated GWP Emissions (tons CO ₂ -e)	Annual Energy consumption (fuel specific units)	Specific Price (\$/MMBtu)	Annual Primary Energy consumption (MMBtu)	Annual Associated cost (\$)	Annual Associated GWP Emissions (tons CO ₂ -e)	Annual Energy consumption (fuel specific units)	Annual Energy Emissions (tons CO ₂ -e)	
Industrial Sector																
Electricity	Electricity	108.6	2.86	44,577,450.00	\$21.04	127,462,788	\$938,060,095.69	2,420,274	108,130,193.05	\$21.04	309,182,630	\$2,275,424,343.79	5,870.7			
Petroleum Look Up	Motor Gasoline	161.8	1.00		\$21.54					\$21.54						
Coal Look Up	Coal Coke	290.5	1.00		\$7.66					\$7.66						
Natural Gas	Natural Gas	130.6	1.00		\$5.79				-222,771,704	\$5.79	-222,771,704	-\$1,290,746,544.34	-14,546.6			
Renewable Look Up	Solar	31.0	1.00		\$14.07					\$14.07						
Steam	Steam and Hot Water*	146.4	1.20		\$4.70					\$4.70						
custom input I																
custom input II																
custom input III																
Transportation Sector																
Electricity	Electricity	108.6	2.86		\$21.04					\$21.04						
Petroleum Look Up	Motor Gasoline	165.3	1.00		\$18.64					\$18.64						
Natural Gas	Natural Gas (pipelines and fuel)	138.2	1.00		\$5.79					\$5.79						
Renewable Fuels	Biomass	165.3	1.00		\$2.89					\$2.89						
custom input I																
custom input II																
custom input III																
Current Annual Energy & Emissions: or equivalently:						127,462,788 MMBtu	\$938,060,095.69	2,420,274 tons CO ₂ -e					Hypothetical Annual Energy & Emissions: or equivalently:			
						127 TBtu		2 million tons CO ₂ -e					86,410,986 MMBtu		\$984,677,799.45	-5,677
													86 TBtu		-9 m	

*Link to reference data tab

References, Notes, and Assumptions

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And the Use Phase Energy tab quantifies the expected energy impacts from the product's final use.

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Manufacturing Capital Expenses (CapEx)

In this tab, you will estimate capital expenses (CapEx - i.e., non-recurring / one-time costs) for the new technology (left) and for the commercial benchmark (right). The reference production volumes (as entered into the Reference Volume tab) are shown below for each technology. If you need to change these, edit in the Reference Volume tab.

Blue Cells: User input - text or numerical

Yellow Cells: User input - select from dropdown

Purple Cells: Default data based on EIA sector averages or standard assumptions (can be user modified if more specific data are available)

Other Cells: Not intended for editing

New Technology (at Industrial Scale)				Commercial Benchmark			
Technology Name	Waste Heat Recovery (Heat Pump)			Technology Name	Evaporative Condenser		
Specific Product	Cooled Waste Water			Specific Product	Cooled Waste Water		
Reference Volume	2.00	Million Gallons	(ref volume) (units)	Reference Volume	2.00	Million Gallons	(ref volume) (units)

For the **new technology**, indicate the annual production volume for the **industrial scale** facility that will be used to assess capital expenses (i.e., one-time expenses). This facility size will also be used as a basis to assess operating expenses in the next tab.

Annual Facility Production of End-Use Product:	730.00	Million Gallons	of cooled Waste Water per year
(facility product.)	(units)		

For the **commercial benchmark**, indicate the annual production volume for the **industrial scale** facility that will be used to assess capital expenses (i.e., one-time expenses). This facility size will also be used as a basis to assess operating expenses in the next tab.

Annual Facility Production of End-Use Product:	730.00	Million Gallons	of cooled Waste Water per year
(facility product.)	(units)		

For both the new technology (left) and commercial benchmark (right), list capital expenses in the tables below. Consider a facility of the size and typical production volume indicated above. For each item listed, name the expense and estimate the purchase price and expected lifetime (for depreciation purposes). For financed equipment, calculate and include the cost of financing. Use the spaces below to list references, assumptions and calculations. Do not include recoverable "working capital" expenses.

A default value of 9% of CapEx annually is assumed for annual equipment and facility maintenance. This value may be adjusted if desired.

New Technology - Capital Expenses (CapEx)							Commercial Benchmark Technology - Capital Expenses (CapEx)													
CapEx Category	Examples	Capital Expense Items (Descriptions)	Purchase Price (\$)	Expected Equipment Lifetime (years)	Annual Capital Cost for Facility (\$)	Capital Cost for Functional Unit (\$)	CapEx Category	Examples	Capital Expense Items (Descriptions)	Purchase Price (\$)	Expected Equipment Lifetime (years)	Annual Capital Cost for Facility (\$)	Scaled Annual Capital Cost (\$)	Capital Cost for Functional Unit (\$)						
Process Equipment	furnaces, reactors	Waste Heat Recovery System (e.g. HRP)	\$254,306	10	\$25,431	\$69.67	Process Equipment	furnaces, reactors	Evaporative condensers (4 total)	\$1,000,000	25	\$40,000	\$40,000	\$109.59						
		Process Equipment Total:							\$25,431	\$70	Process Equipment Total:						\$40,000	\$40,000	\$109.59	
		Non-process Equipment							\$14,229	\$3.91	Non-process Equipment						\$14,229	\$3.91		
Non-process Equipment	piping, control systems, power equipment	Piping	\$50,000	35	\$14,229	\$3.91	Non-process Equipment	piping, control systems, power equipment	Piping	\$50,000	35	\$14,229	\$14,229	\$3.91						
		Non-Process Equipment Total:							\$14,229	\$4	Non-Process Equipment Total:						\$14,229	\$3.91		
Engineering & Construction	engineering, design, procurement, construction	Design	\$10,000	15	\$667	\$1.83	Engineering & Construction	engineering, design, procurement, construction	Design	\$400		\$400	\$400	\$1.10						
		Installation	\$127,153	15	\$8,477	\$23.22			Installation	\$20,000		\$20,000	\$20,000	\$54.79						
Engineering & Construction Total:						\$8,477	\$23.22	Engineering & Construction Total:						\$20,400	\$55.89					

CapEx

OpEx

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The two tabs in the Economic Considerations category house economic operations data on the project.

(facility product.) (units) (facility product.) (units)

For both the new technology (left) and commercial benchmark (right), list capital expenses in the tables below. Consider a facility of the size and typical production volume indicated above. For each item listed, name the expense and estimate the purchase price and expected lifetime (for depreciation purposes). For financed equipment, calculate and include the cost of financing. Use the spaces below to list references, assumptions and calculations. Do not include recoverable "working capital" expenses.

A default value of 5% of CapEx annually is assumed for annual equipment and facility maintenance. This value may be adjusted if desired.

New Technology - Capital Expenses (CapEx)							Commercial Benchmark Technology - Capital Expenses (CapEx)				
CapEx Category	Examples	Capital Expense Items (descriptions)	Purchase Price (\$)	Expected Equipment Lifetime (years)	Annual Capital Cost for Facility (\$)	Capital Cost for Functional Unit (\$)	CapEx Category	Examples	Capital Expense Items (descriptions)	Purchase Price (\$)	Expected Equipment Lifetime (years)
Process Equipment	furnaces, reactors	Waste Heat Recovery System (e.g. IHP)	\$254,306	10	\$25,431	\$69.67	Process Equipment	furnaces, reactors	Evaporative condensers (4 total)	\$1,000,000	2
Process Equipment Total:					\$25,431	\$70	Process Equipment Total:				
Non-process Equipment	piping, control systems, power equipment	Piping	\$50,000	35	\$1,429	\$3.91	Nonprocess Equipment	piping, control systems, power equipment.	Piping	\$50,000	3
Non-Process Equipment Total:					\$1,429	\$4	Non-Process Equipment Total:				
Engineering & Construction	engineering, design, procurement, construction	Design	\$10,000	15	\$667	\$1.83	Engineering & Construction	engineering, design, procurement, construction	Design	\$10,000	2
		Installation	\$127,153	15	\$8,477	\$23.22					\$500,000
Engineering & Construction Total:					\$9,144	\$25	Engineering & Construction Total:				
Other CapEx	land, commissioning, contingency						Other CapEx	land, commissioning, contingency, spare parts.			
Other CapEx Total:							Other CapEx Total:				
Total capital Expense:					\$36,003	\$98.64	Total capital Expense:				
Annual Capital Equipment/Facility Maintenance (typical value 5%):					5%	5%	Annual Capital Equipment/Facility Maintenance (typical value 5%):				

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The CapEx (or capital expenses) tab captures the expenses for manufacturing equipment along with other purchase costs required to produce these technologies at the established scale.

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Manufacturing Operating Expenses (OpEx)

In this tab, you will estimate operating expenses (OpEx - i.e., recurring costs) for the new technology (left) and for the commercial benchmark (right). Operating expenses include labor, materials, energy, and other recurring costs. Materials and energy costs were calculated in prior tabs and data are reproduced here for convenience (entries may be edited directly in the Raw Materials and Manufacturing Energy tabs if edits are needed). You will enter data only for labor and (optional) other recurring costs in the blue cells of this tab. In estimates, consider the annual costs for a facility of the size indicated in the CapEx tab. The reference production quantities (as entered into the Reference Quantity tab) and facility production quantities (as entered into the CapEx tab) are shown below for each technology.

New Technology (at Industrial Scale)				Commercial Benchmark			
Technology Name	Waste Heat Recovery (Heat Pump)			Technology Name	Evaporative Condenser		
Specific Product	Cooled Waste Water			Specific Product	Cooled Waste Water		
Reference Production Quantity	2.00	Million Gallons		Reference Quantity	2.00	Million Gallons	
Annual Facility Production Quantity	730.00	Million Gallons		Annual Facility Production Quantity	730.00	Million Gallons	
	(quantity)	(units)			(quantity)	(units)	

Direct Labor Costs
 Estimate annual direct (operating) labor costs in the blue cells below, considering a facility of the size and annual production indicated in the CapEx tab. By default, annual costs are calculated from the number of full-time-equivalent (FTE) employees and annual pay rates. If data are available as a total annual labor cost instead, data may be entered directly in the "Labor Cost (\$ per year)" column, over-writing the default formulas. Do not include administrative labor in this section. The default percentage for fringe benefits and general overhead is 72% (considered a typical value) but this can be overwritten if needed. If labor costs are unknown, rules-of-thumb based estimation methods may be used. See the tab linked below for rules of thumb (and a calculator that will aid you in completing this section).
[Calculation Tool: Labor Cost Estimation Rules-of-Thumb](#)

New Technology - Direct Labor Costs					Commercial Benchmark - Direct Labor Costs								
	Number of FTE Employees	Average Annual Pay Rate	Employee Fringe Benefits & General Overhead Rate (%)	Annual Labor Cost (\$ for facility of size shown above)	Labor Cost (\$) (per reference quantity)		Number of FTE Employees	Average Annual Pay Rate	Employee Fringe Benefits & General Overhead Rate (%)	Annual Labor Cost (\$ for facility of size shown above)	Scaled Annual Labor Cost (\$) (adjusted to new tech. facility size)	Labor Cost (\$) (per reference quantity)	
Direct Labor (equipment operators & supervisors)	0.00962	\$75,000	72%	\$1,240	\$3.40		0.0332	\$75,000	72%	\$4,279	\$4,279	\$11.72	
Total Operating Labor Cost:				\$1,240	\$3.40		Total Operating Labor Cost:				\$4,279	\$4,279	\$11.72
				730 Million Gallons Annual Facility Production	2 Million Gallons (Reference Quantity)						730 Million Gallons Annual Facility Production	730 Million Gallons Scaled Facility Production, New Tech Equivalent	2 Million Gallons (Reference Quantity)

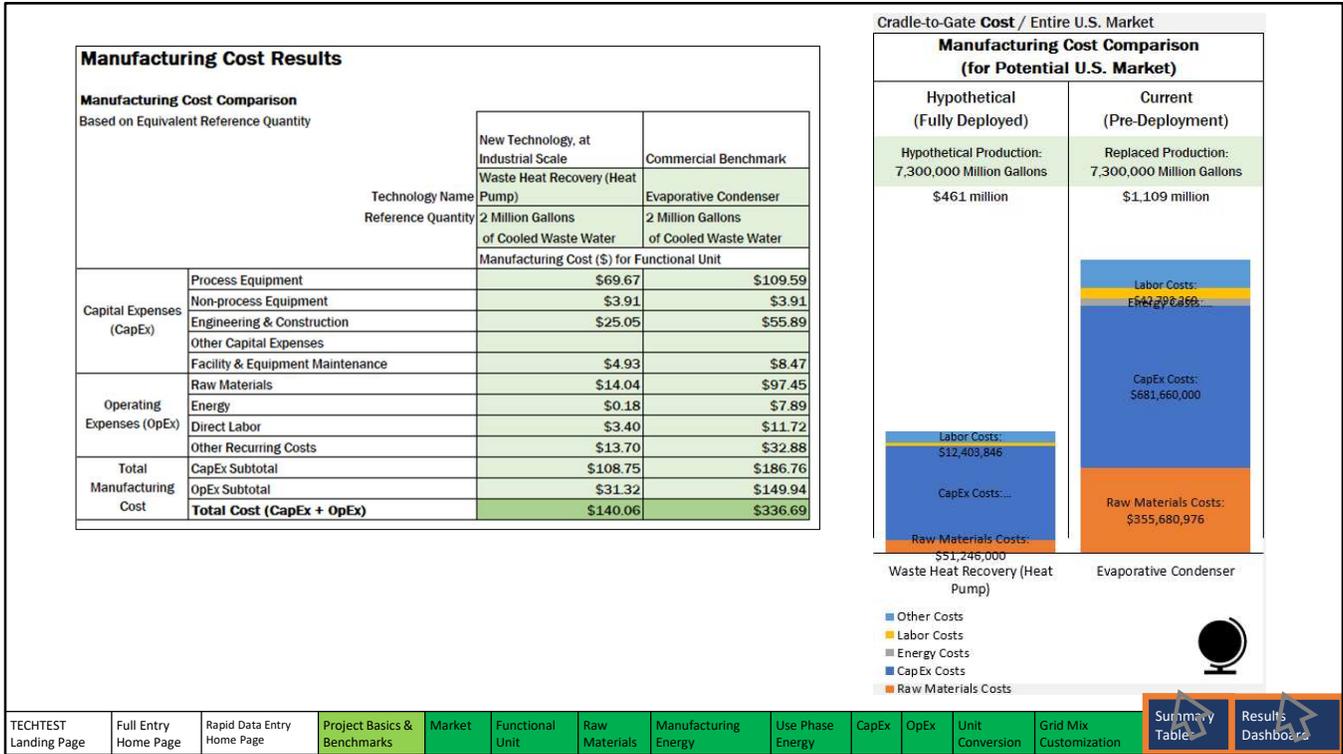
Raw Materials Costs
 Materials costs entered into the "Raw Materials" tab are reprinted here for convenience. If data need to be adjusted, make changes in the Raw Materials tab.

New Technology - Raw Material Inputs					Commercial Benchmark - Raw Material Inputs				

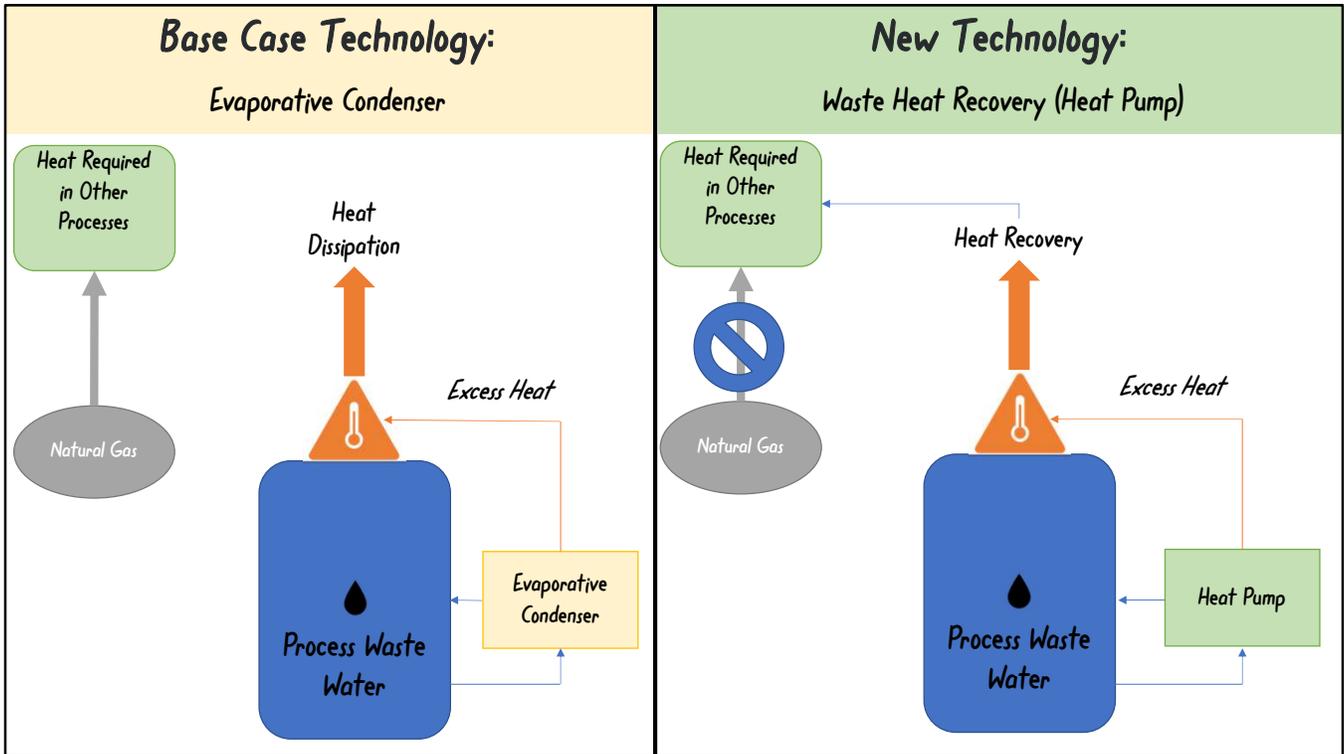
Entered Amount

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The OpEx (or operating expenses) tab models the ongoing cost of operating the manufacturing equipment, through a measure of labor costs and other dynamic cost considerations.



Finally, the two Results tabs will showcase the results of your TECHTEST analysis, in table form in the Summary Tables tab and graphically in the Results Dashboard tab. Now that the general TECHTEST framework has been established, let's get started with our example scenario.



For this example, we will use the Full Analytical Approach to analyze a new waste heat recovery technology involving a heat pump being used to cool process wastewater and compare it to the benchmark technology of using evaporative coolers to achieve the required heat removal. The heat recovered by the heat pump can be utilized upstream for process heating needs, offsetting natural gas purchases that would otherwise be required.

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Project & Technology Description

Project Title	Waste Heat Recovery Cooling in Beverage Manufacturing
Lead Organization	Hypothetical Organization
Collaborative Partner(s)	Staff
Principal Investigator Name	John Doe
Principal Investigator Organization	Hypothetical National Laboratory
AMO Technology Manager	Jane Doe
Project Start	January-23
Project End	January-25
Funding Mechanism	R&D Project

Energy, Emissions & Cost Impact Drivers *Note: This section examines emissions over the entire lifecycle.*

Energy & Emissions Impacts by Life Cycle Phase	In your opinion, would this technology be likely to impact the energy and/or emissions associated with ...	Yes/No	Mechanism <i>(Explain why this technology would be likely to have an impact.)</i>
	... raw materials used in the manufacturing process?		
	... manufacturing the end-use product?		
	... using, transporting, or disposing of the end-use product?		

Manufacturing Cost Impacts by Cost Component	In your opinion, would this technology be likely to impact the manufacturing costs associated with ...	Yes/No	Mechanism
	... capital equipment?		
	... raw materials used in manufacturing?		
	... energy used in manufacturing?		

labor?

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In the Project Basics & Benchmarks tab, we will identify where improvements may occur with respect to the new technology. The data input sections of this tab include: general project information; the generic market end-use product; definitions of competing technologies and products; and the energy, emissions, and cost impact drivers.

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Project & Technology Description

Project Title	Waste Heat Recovery Cooling in Beverage Manufacturing
Lead Organization	Hypothetical Organization
Collaborative Partner(s)	Staff
Principal Investigator Name	John Doe
Principal Investigator Organization	Hypothetical National Laboratory
AMO Technology Manager	Jane Doe
Project Start	January-23
Project End	January-25
Funding Mechanism	R&D Project

Generic Market End-Use Product*:

* The "generic" market end-use product should be defined generally enough to encompass the end-use products of all competing technologies (new technology, commercial benchmark, other competing technologies), if the end products are different but would be used to serve the same function. Specific differences in the end products or applications can be specified in the table below.

Definitions of Competing Technologies and Products

	Technology Definition	Specific Product or Application	Technology Status
	<i>Define the technology.</i>	<i>Identify the end-use products and/or key applications for this technology, noting any differences.</i>	<i>Is this technology a current typical technology, a state-of-the-art technology, or an emerging technology?</i>
New Technology (developed in this project)	<i>Waste Heat Recovery (Heat Pump)</i>	<i>Cooled Waste Water</i>	<i>Typical Technology</i>
Commercial Benchmark Technology	<i>Evaporative Condenser</i>	<i>Cooled Waste Water</i>	<i>Typical Technology</i>
Other Competing Technologies <i>(list relevant technologies, separating by commas)</i>			

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We will enter the end-use product as “cooled waste water,” defining the new and commercial benchmark technologies as “Waste Heat Recovery (Heat Pump)” and “Evaporative Condenser,” respectively.

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Project & Technology Description

Project Title **Waste Heat Recovery Cooling in Beverage Manufacturing**

Energy, Emissions & Cost Impact Drivers

Note: This section examines emissions over the entire lifecycle.

Energy & Emissions Impacts
by Life Cycle Phase

In your opinion, would this technology be likely to impact the energy and/or emissions associated with ...	Yes/No	Mechanism <i>(Explain why this technology would be likely to have an impact.)</i>
... raw materials used in the manufacturing process?	Yes	Higher energy efficiency, no cooling water needed
... manufacturing the end-use product?		
... using, transporting, or disposing of the end-use product?		

Manufacturing Cost Impacts
by Cost Component

In your opinion, would this technology be likely to impact the manufacturing costs associated with ...	Yes/No	Mechanism
... capital equipment?		
... raw materials used in manufacturing?		
... energy used in manufacturing?		
... manufacturing labor?		

Impacts by Sector

For each sector that would be impacted by the new technology, briefly describe the mechanisms of potential impacts. (Assume successful commercialization and adoption.)

In your opinion, would this technology be likely to impact the following sectors (energy, emissions, or cost)?	Yes/No	Mechanism
Mining	Yes	Used to save energy in beverage manufacturing
Manufacturing		
Transportation		
Energy Generation (utility scale)		
Energy Generation (device scale)		

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We then identify the areas where the new technology could see improvements over the benchmark.

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Market Size

Annual U.S. Production of End-use Product: of (end-use product not yet defined) per year
(all U.S. production, all facilities) (units)

The amount of cooled wastewater produced at 10,000 towers nationwide over 365 days

Market Breakdown

	Pre-Deployment	Full Deployment
		Market Share (%):

References, Notes, and Assumptions

List key references and assumptions used to prepare the data provided in this sheet. Add as many rows as needed.

Calculations

Use this section for project-specific calculations and detailed references supporting the data above. Add as many rows as needed.

$$2 * 10,000 * 365 = 7,300,000$$

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On the Market tab, we input the total annual production of the end-use product at all U.S. facilities (in this case, the amount of cooled waste water produced at 10,000 towers nationwide over 365 days), as well as the hypothetical use percentages for each technology. There is also space to add references, notes, assumptions, and calculations; this space appears at the bottom of each data input tab.

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Functional Units and Reference Quantities

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An explanation of best practices for choosing a functional unit can be found in DOE's "Functional Units" short tutorial video: https://www.youtube.com/watch?v=6_5j8kTomOo&ab_channel=U.S.DepartmentofEnergy

A **Functional Unit** defines the quantity of a product or product system based on the performance it delivers in its end-use application. The purpose of defining a performance-based functional unit is to facilitate accurate comparisons (of environmental or cost metrics) for disparate products or systems that serve the same final function. The functional unit can be used to objectively compare commercial benchmark technology. The process can be broken down into two steps:

Step 1: Based on the functional unit, specify a reference quantity for the New Technology that can be compared to an equivalent reference quantity for the Commercial Benchmark Technology.

Use the functional unit to specify a production reference quantity for the new technology, as shown in the examples below.

Functional Unit Based Reference Quantity for the New Technology: of for New Technology

Value Unit of Product

Examples: 80 kg of new ethylene catalyst
1,000,000 lumen-hours produced by a new LED bulb
9 kg of dual-phase high strength steel
18 recycled polymer pallet shipping pallets in novel design

Finally, specify the performance-equivalent production reference quantity for the commercial benchmark technology, as shown in the examples below. Note that this value may vary from the reference quantity for the new technology. It depends on how you've defined your functional unit, and whether the new technology will serve as a drop-in replacement for the commercial benchmark technology.

Performance Equivalent Reference Quantity for the Commercial Benchmark: of for Commercial Benchmark Technology

Value Unit of Product

Examples: 90 kg of conventional ethylene catalyst
1,000,000 lumen-hours produced by a current typical lightbulb
13 kg of conventional mild steel
24 conventional wood stringer pallets

Note: the functional unit and reference quantity are the basis of comparison for the entire assessment.

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On the Functional Unit tab, we establish 2 million gallons of cooled waste water (the typical daily output of a water tower) as our reference quantity. Despite differences in the process, both technologies will produce the same amount of water, so our equivalent reference quantity stays the same.

Note that the functional unit, and reference quantity, are the basis of comparison for the entire assessment, so it is important to ensure consistency between the new and benchmark technologies. If you are unfamiliar with establishing a functional unit, we recommend viewing the "Defining Functional Units" tutorial video, linked at the top of the Functional Unit tab.

Life Cycle Impacts: Manufacturing Energy

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Manufacturing Energy, Emissions, and Energy Costs

Estimate onsite energy consumption (in the blue input cells) by energy/fuel type. Energy consumption totals should correspond to the reference quantity of finished product of the new technology (left) and commercial benchmark technology (right) to facilitate comparisons. Default data are provided for energy prices, GWP, and source-to-site ratio (see Summary Ref Tables tab) and can be user-adjusted from the default values for greater accuracy, if better estimates are available. IPCC AR5 values for 100-Year Global Warming Potential (GWP) are associated with energy consumption. See the GWP & Combustion Data tab (linked below) for source data and assumptions.

New Technology (at Industrial Scale)

Technology Name: Waste Heat Recovery (Heat Pump)
 Specific Product: Cooled Waste Water
 Reference Quantity: 2.00 Million Gallons
 (quantity) (units)

New Technology - Energy Consumption & Cost Data (to produce reference quantity)

Data entry ↓ Default sector data* (Can be modified if needed. If modifying value, change background color to blue)

Fuel or Energy Type	Energy Source (Dropdowns available for Petroleum, Coal, and Renewable)	Onsite Energy Consumption* (MMBtu)	Specific Price (\$/MMBtu)	Specific 100-yr GWP (lb CO2-eq / MMBtu)	Source-to-Site Ratio (electricity and steam only)	Primary Energy Consumption, including offsite losses (MMBtu)
Electricity	Electricity		\$21.04	108.6	2.86	
Petroleum						
Coal						
Natural Gas	Natural Gas		\$5.79	130.6	1.00	
Renewable						
Steam	Steam and Hot Water**		\$4.70	146.4	1.20	
Custom Input I						
Custom Input II						
Custom Input III						

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The Manufacturing Energy tab calculates the energy required to “manufacture” the reference quantity.

Fuel or Energy Type	Energy Source (Dropdowns available for Petroleum, Coal, and Renewable)	Onsite Energy Consumption* (MMBtu)	Specific Price (\$/MMBtu)
Electricity	Electricity		\$
Petroleum			
Coal	Asphalt (bitumen) and road oil		
Natural Gas	Diesel & distillate fuel oil		
Renewable	Liquified Petroleum Gas		
Steam	Kerosene		
Custom Input I	Motor Gasoline		
Custom Input II	Petroleum Coke		
	Residual Fuel Oil		
Custom Input III	Other Petroleum		

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Energy sources can be selected from dropdown lists within the yellow cells.

Source for Petroleum, (available)	Onsite Energy Consumption* (MMBtu)	Specific Price (\$/MMBtu)	Specific 100-yr GWP (lb CO2-eq / MMBtu)	Source-to-Site Ratio (electricity and steam only)
		\$21.04	108.6	2.86
	<input type="text" value="▼"/>	\$11.14	188.3	1.00
		\$5.79	130.6	1.00
		\$4.70	146.4	1.20

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Notice that the values in the purple cells automatically populate after you identify the energy sources in the dropdown.

All energy cost inputs should be on a per-functional-unit basis

Category	Energy Source	CO2 Emissions Factor (kg of GHG per TJ)	CH4 Emissions Factor (kg of GHG per TJ)	N2O Emissions Factor (kg of GHG per TJ)	Calculated 100-Year GWP Emissions (kg CO2-eq per TJ)	Calculated 100-Year GWP Emissions (lbs CO2-eq per MMBtu)*
Petroleum	Bitumen (asphalt)	80,700	3	0.6	80,945	188.3
	Gas / Diesel Oil (distillate fuel oil)	74,100	3	0.6	74,345	172.9
	Liquified Petroleum Gas	63,100	1	0.1	63,154	146.9
	Kerosene	71,900	3	0.6	72,145	167.8
	Motor Gasoline	69,300	3	0.6	69,545	161.8
	Petroleum Coke	97,500	3	0.6	97,745	227.4
	Residual Fuel Oil	77,400	3	0.6	77,645	180.6
Coal	Other Petroleum	73,300	3	0.6	73,545	171.1
	Coke Oven Coke and Lignite Coke	107,000	10	1.5	107,680	250.5
	Bituminous Coal	94,600	3	1.5	95,091	221.2
	Anthracite	98,300	3	1.5	98,791	229.8
Natural Gas	Lignite	101,000	3	1.5	101,491	236.1
	Natural Gas	56,100	1	0.1	56,154	130.6
	Municipal Waste (biomass)	100,000	30	4.0	101,902	237.0
Renewable Fuels	Industrial Wastes	143,000	30	4.0	144,902	337.0
	Wood / Wood Waste	112,000	30	4.0	113,902	264.9
	Biogasoline & Biodiesel	70,800	3	0.6	71,045	165.3
Steam	Steam and Hot Water**	62,872	1	0.1	62,936	146.4

ini-Tool

MFI Embodied Energy Mini-Tool

Labor Estimation Mini-Tool

GWP Ref Tables

EIA Ref Tables

Summary Ref Tables

If necessary, you can customize the specific prices, global warming potentials, and source-to-site ratios by modifying these values in the GWP Ref Tables and EIA Ref Tables tabs. And remember, all energy cost inputs should be on a per-functional-unit basis.

New Technology - Energy Consumption & Cost Data (to produce reference quantity)

New Technology: Heat Pump

Data entry ↓ Default sector data* (Can be modified if needed. If modifying value, change background color to blue)

Fuel or Energy Type	Energy Source (Dropdowns available for Petroleum, Coal, and Renewable)	Onsite Energy Consumption* (MMBtu)	Specific Price (\$/MMBtu)	Specific 100-yr GWP (lb CO2-eq / MMBtu)	Source-to-Site Ratio (electricity and steam only)	Primary Energy Consumption, including offsite losses (MMBtu)	Energy Cost (\$)	GWP Emissions (lb CO2-eq)
Electricity	Electricity	0.0048	\$21.04	108.6	2.86	0.01 MMBtu	\$0.10	0.5 lb CO2-e
Petroleum								
Coal								
Natural Gas	Natural Gas	0.0133	\$5.79	130.6	1.00	0.01 MMBtu	\$0.08	1.7 lb CO2-e
Renewable								
Steam	Steam and Hot Water**		\$4.70	146.4	1.20			
Custom Input I								
Custom Input II								
Custom Input III								
						0.03 MMBtu	\$0.18	2.3 lb CO2-e

Commercial Benchmark - Energy Consumption & Cost Data (to produce reference quantity)

Benchmark: Evaporative Condenser

Data entry ↓ Default sector data* (Can be modified if needed. If modifying value, change background color to blue)

Fuel or Energy Type	Energy Source (Dropdowns available for Petroleum, Coal, and Renewable)	Onsite Energy Consumption* (MMBtu)	Specific Price (\$/MMBtu)	Specific 100-yr GWP (lb CO2-eq / MMBtu)	Source-to-Site Ratio (electricity and steam only)	Primary Energy Consumption, including offsite losses (MMBtu)	Energy Cost (\$)	GWP Emissions (lb CO2-eq)
Electricity	Electricity	0.370	\$21.04	108.6	2.86	1.06 MMBtu	\$7.81	40.3 lb CO2-e
Petroleum								
Coal								
Natural Gas	Natural Gas	0.010	\$5.79	130.6	1.00	0.01 MMBtu	\$0.08	1.7 lb CO2-e
Renewable								
Steam	Steam and Hot Water**		\$4.70	146.4	1.20			
Custom Input I								
Custom Input II								
Custom Input III								
						1.07 MMBtu	\$7.89	42.1 lb CO2-e

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For our example scenario, we enter the associated electricity and natural gas onsite energy consumptions for manufacturing both technologies, based on the 2-million-gallon reference quantity.

Manufacturing Process Emissions (if applicable)

If there are process emissions associated with either the new technology or commercial benchmark technology, list the emissions and associated 100-year GWP below. Do not include if there are no significant process emissions, leave this section blank.

*New Technology:
Heat Pump*

New Technology - Process Emissions (to produce reference volume)

Emission Type (chemical name or acronym)	Amount emitted (lb)	100-Year GWP*	Suggested 100-Year GWP	Embodied Carbon (lb CO2-eq)
R-134a	0.05	1,300		64 lbs CO2-e
Total:				64 lbs CO2-e

* Use IPCC AR5 values for 100-Year Global Warming Potential (GWP). See the GWP Data tab (linked below) for excerpted GWP values for the most common refrigerants.
[Reference Data Tables: Global Warming Potential](#)

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In this tab, we will also enter the manufacturing process emissions (if applicable) that result from manufacturing the reference quantity. In this case, emissions associated with the refrigerant used in the new waste heat recovery technology are entered.

Life Cycle Impacts: Use Phase Energy

Expected impacts from the product's final use are quantified

The change in total annual energy consumption is calculated assuming the new technology reaches maximum market adoption overnight.

U.S. DEPARTMENT OF ENERGY (DOE) OFFICE OF ENERGY EFFICIENCY AND RENEWABLE ENERGY (EERE)
Techno-economic, Energy & Carbon Heuristic Tool for Early Stage Technologies (TECHTEST)

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Use Phase Energy and Emissions

Blue Cells: User input - text or numerical
 Yellow Cells: User input - select from dropdown
 Purple Cells: Default data based on EIA sector averages or standard assumptions (can be user modified if more specific data are available)
 Other Cells: Not intended for editing

Complete this tab for any technology expected to have an energy impact during final use of the finished product in its end-use sector. Technologies for which the Use Phase is important include energy-consuming device savings (compared to typical materials) when used in a vehicle; and an energy-efficient device may provide electricity savings (compared to typical devices) when used in a consumer application. If the technology is not a technology where the end-use product is identical to that produced using current typical technologies. For example, a new production route for a commodity chemical would not be expected to have use phase impact.

To evaluate the use phase energy impact, estimate the total U.S. annual energy consumption (for the end-use market impacted by the technology) based on two scenarios:

1. Current Annual Energy Consumption
2. Hypothetical Annual Energy Consumption, Based on "Overnight Replacement" with New Technology

In the "Current" scenario, assume the current market size and market conditions. Consider the entire market, including all facilities and manufacturers. In the "Overnight Replacement" scenario, assume a hypothetical market conditions held constant (this is a simplification).

Enter data on an annual basis in the blue cells below, considering the U.S. market and breaking down by sector and energy source. Enter data only into rows for sector(s) and energy sources as in the purple cells. These data may be over-written if more accurate facility- or industry-specific data are available. Provide your references, assumptions, source data, and calculations in the sections at the bottom of 1

Default sector data* (can be modified if needed) ↓ Data entry** ↓

Sector & Energy Type	Energy Source	Specific 100-yr GWP (lb CO2-eq / MMBtu)	Source-to-Site Ratio (Btu primary / Btu onsite)	Annual Energy Consumption (fuel specific units)	Specific Price (\$/MMBtu)	Annual Primary Consumption
Industrial Sector						
Electricity	Electricity	108.6	2.86			\$21.04
Petroleum Look Up		#N/A	1.00			#N/A
Coal Look Up		#N/A	1.00			#N/A
Natural Gas	Natural Gas	130.6	1.00			\$5.79
Renewable Look Up		#N/A	1.00			#N/A
Steam	Steam and Hot Water*	146.4	1.20			\$4.70
Custom Input I						
Custom Input II						
Custom Input III						

Hypothetical Annual Energy & En (based on "overnight replacement")

TECHTEST Landing Page Full Entry Home Page Rapid Data Entry Home Page Project Basics & Benchmarks Market Functional Unit Raw Materials Manufacturing Energy **Use Phase Energy** CapEx OpEx Unit Conversion Grid Mix Customization Summary Tables Results Dashboard

The Use Phase Energy tab is where expected energy impacts from the product's final use are quantified for both the new and benchmark technologies. Because the use phase energy depends on the size of the end-use market, the change in total U.S. annual energy consumption is calculated assuming the new technology reaches maximum market adoption overnight.

New Technology: Heat Pump

Default sector data*
(can be modified if needed)
↓

Data entry**
↓

Hypothetical Annual Energy & Emissions - Product Use Phase (based on "overnight replacement" with new technology)

Sector & Energy Type	Energy Source	Specific 100-yr GWP (lb CO2-eq / MMBtu)	Source-to-Site Ratio (Btu primary / Btu onsite)	Annual Energy Consumption (fuel specific units)	Specific Price (\$/MMBtu)	Annual Primary Energy Consumption (MMBtu)	Annual Associated Cost (\$)	Annual Associated GWP Emissions (tons CO2-eq)
Industrial Sector								
Electricity	Electricity	108.6	2.86	108,130,193 MMBtu	\$21.04	309,182,690 MMBtu	\$2,275,424,343.79	5,870,785 tons CO2-e
Petroleum Look Up		#N/A	1.00		#N/A			
Coal Look Up		#N/A	1.00		#N/A			
Natural Gas	Natural Gas	130.6	1.00	-222,771,704 MMBtu	\$5.79	-222,771,704 MMBtu	-\$1,290,746,544.34	-14,548,652 tons CO2-e
Renewable Look Up		#N/A	1.00		#N/A			
Steam	Steam and Hot Water*	146.4	1.20		\$4.70			
Custom Input I								
Custom Input II								
Custom Input III								

Benchmark: Evaporative Condenser

Default sector data*
(can be modified if needed)
↓

Data entry**
↓

Current Annual U.S. Energy & Emissions - Product Use Phase (based on current technologies in use)

Sector & Energy Type	Energy Source	Specific 100-yr GWP (lb CO2-eq / MMBtu)	Source-to-Site Ratio (Btu primary / Btu onsite)	Annual Onsite Energy Consumption (MMBtu)	Specific Price (\$/MMBtu)	Annual Primary Energy Consumption, including offsite losses (MMBtu)	Annual Associated Cost (\$)	Annual Associated GWP Emissions (tons CO2-eq)
Industrial Sector								
Electricity	Electricity	108.6	2.86	44,577,450 MMBtu	\$21.04	127,462,788 MMBtu	\$938,060,055.69	2,420,274 tons CO2-e
Petroleum Look Up		#N/A	1.00		#N/A			
Coal Look Up		#N/A	1.00		#N/A			
Natural Gas	Natural Gas	130.6	1.00		\$5.79			
Renewable Look Up		#N/A	1.00		#N/A			
Steam	Steam and Hot Water*	146.4	1.20		\$4.70			
Custom Input I								
Custom Input II								
Custom Input III								

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Here we will calculate the electricity costs, scaled up to annual usage, for both technologies. Additionally, the heat pump reduces natural gas usage by transporting heat for process use elsewhere in the system. We can account for this by adding a negative input for natural gas. Note that negative inputs can be used throughout TECHTEST to show avoided emissions.

References, Notes, and Assumptions														
<p>List key references and assumptions used to prepare the data provided in this sheet. Add as many rows as needed.</p>			IHP Calculations: https://www.energy.gov/sites/prod/files/2014/05/f15/heatpump.pdf											
<p>Calculations</p> <p>Use this section for project-specific calculations and detailed references supporting the data above. Add as many rows as needed.</p> <p>Commercial Benchmark Electricity Usage via Evaporative Cooling Units</p> <p>4 fans at 50 hp each operator to cool this water, so to estimate electricity required: $100 \text{ hp} * 4 \text{ fans} * 0.7457 \text{ kW/hp} * 24 \text{ hours per day} = 3579.36 \text{ kWh}$ from grid used to cool 2 million gallons of wastewater each day $3579.36 \text{ kWh} * 3412.14 \text{ BTU / kWh} * 1 \text{ MMBTU}/1000000 \text{ BTUs} = 12.213 \text{ MMBTUs per day in electricity consumption for grid to cool 2 million gallons of wastewater a day}$</p> <p>Waste Heat Recovery Unit/Heat Pump Calculations for Electricity Usage Required and Heating Captured/Delivered by Heat Pump</p> <p>Source: https://www.energy.gov/sites/prod/files/2014/05/f15/heatpump.pdf **see page 12</p> <p>Approach Temp: 20 dF **assumed value based on DOE source above</p> <p>Working Fluid</p> <p>T_{in}: 80 dF</p> <p>T_{out}: 195 dF **assume heat generated would replace steam heat required for sterilization/hot water at 175 dF</p> <p>Heat Source (i.e. WWTR stream)</p> <p>T_{in}: 105 dF</p> <p>T_{out}: 100 dF</p>														
TECHTEST Landing Page	Full Entry Home Page	Rapid Data Entry Home Page	Project Basics & Benchmarks	Market	Functional Unit	Raw Materials	Manufacturing Energy	Use Phase Energy	CapEx	OpEx	Unit Conversion	Grid Mix Customization	Summary Tables	Results Dashboard

The entered values are determined in the Calculations section at the bottom of this tab.

Sector & Energy Type	Energy Source	Specific 100-yr GWP (lb CO2-eq / MMBtu)	Source-to-Site Ratio (Btu primary / Btu onsite)	Annual Energy Consumption (fuel specific units)
Transportation Sector				
Electricity	Electricity	108.6	2.86	
Petroleum Look Up		#N/A	1.00	
Natural Gas	Natural Gas (pipelines and fuel)	138.2	1.00	
Renewable Fuels	Biomass	165.3	1.00	
Custom Input I				
Custom Input II				
Custom Input III				

Hypothetical Annual Energy & Emissions: or equivalently:

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The transportation sector does not apply to our waste heat recovery scenario, so only energy impacts in the industrial sector are entered.

Economic Considerations:

CapEx

Captures the expenses for machinery and other one-time purchases required to manufacture the established functional unit.

Note: these costs are often independent of the volume of product produced.

Data inputs include:

- Process equipment*
- Non-process equipment*
- Engineering*
- Construction*
- Other one-time costs*

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Manufacturing Capital Expenses (CapEx)

In this tab, you will estimate capital expenses (CapEx - i.e., non-recurring / one-time costs) for the new technology (left) and for the commercial benchmark (right). The reference production quantities (as entered into the Functional Unit tab) are shown below for each technology. If you need to change these, edit in the Functional Unit tab.

New Technology (at Industrial Scale)		Commercial Benchmark
Technology Name	Waste Heat Recovery (Heat Pump)	Technology Name
Specific Product	Cooled Waste Water	Specific Product
Reference Quantity	2.00 Million Gallons	Reference Quantity
	(quantity) (units)	

For the **new technology**, indicate the annual production volume for the **industrial scale facility** that will be used to assess capital expenses (i.e., one-time expenses). This facility size will also be used as a basis to assess operating expenses in the next tab. For the **commercial benchmark**, indicate the annual production volume for the **commercial scale facility** that will be used to assess capital expenses (i.e., one-time expenses). This facility size will also be used as a basis to assess operating expenses in the next tab.

Annual Facility Production of End-use Product:	<input type="text"/>	Million Gallons	of (end-use product not yet defined) per year	Annual Facility Production of End-use Product:	<input type="text"/>	Million Gallons	of (end-use product not yet defined) per year
	(facility product.)	(units)			(facility product.)	(units)	

For both the new technology (left) and commercial benchmark (right), list capital expenses in the tables below. Consider a facility of the size and typical product above. For each item listed, name the expense and estimate the purchase price and expected lifetime (for depreciation purposes). For financed equipment, include the cost of financing. Use the spaces below to list references, assumptions and calculations. Do not include recoverable "working capital" expenses.

A default value of 5% of CapEx annually is assumed for annual equipment and facility maintenance. This value may be adjusted if desired.

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Moving on to the Economic Considerations category, the CapEx (or capital expenses) tab captures the expenses for machinery and other one-time purchases required to manufacture the established functional unit. However, note that these costs are often independent of the volume of product produced. Data inputs here include process and non-process equipment, engineering, construction, and any other one-time costs required to commission the referenced technology.

For the **new technology**, indicate the annual production volume for the industrial scale facility that will be used to assess capital expenses (i.e., one-time expenses). This facility size will also be used as a basis to assess operating expenses in the next tab.

Annual Facility Production of End-use Product:	730	Million Gallons	of (end-use product not yet defined) per year
	(facility product.)	(units)	

For the **commercial benchmark**, indicate the annual production volume for the industrial scale facility that will be used to assess capital expenses (i.e., one-time expenses). This facility size will also be used as a basis to assess operating expenses in the next tab.

Annual Facility Production of End-use Product:	730	Million Gallons	of (end-use product not yet defined) per year
	(facility product.)	(units)	

TECHTEST Landing Page	Full Entry Home Page	Rapid Data Entry Home Page	Project Basics & Benchmarks	Market	Functional Unit	Raw Materials	Manufacturing Energy	Use Phase Energy	CapEx	OpEx	Unit Conversion	Grid Mix Customization	Summary Tables	Results Dashboard
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We start by entering the annual facility output of the functional unit (not the reference quantity) for both technologies.

New Technology: Heat Pump

Benchmark: Evaporative Condenser

New Technology - Capital Expenses (CapEx)

CapEx Category	Examples	Capital Expense Items (descriptions)	Purchase Price (\$)	Expected Equipment Lifetime (years)	Annual Capital Cost for Facility (\$)	Capital Cost for Functional Unit (\$)
Process Equipment	furnaces, reactors	<i>WHR - Heat Pump</i>	<i>\$254,306</i>	<i>10</i>	<i>\$25,431</i>	<i>\$69.67</i>
Process Equipment Total:					<i>\$25,431</i>	<i>\$69.67</i>
Non-process Equipment	piping, control systems, power equipment	<i>Piping</i>	<i>\$50,000</i>	<i>35</i>	<i>\$1,429</i>	<i>\$3.91</i>
Non-Process Equipment Total:					<i>\$1,429</i>	<i>\$3.91</i>
Engineering & Construction	engineering, design, procurement, construction	<i>Design</i>	<i>\$10,000</i>	<i>15</i>	<i>\$667</i>	<i>\$1.83</i>
		<i>Installation</i>	<i>\$127,153</i>	<i>15</i>	<i>\$8,477</i>	<i>\$23.22</i>
Engineering & Construction Total:						<i>\$25.05</i>
Other CapEx	land, commissioning, contingency					
Other CapEx Total:					<i>\$36,003</i>	<i>\$98.64</i>
Total Capital Expense:						
Annual Capital Equipment/Facility Maintenance (typical value 5%):					5%	5%
Total Capital Expense, Including Maintenance:					<i>\$37,803</i>	<i>\$98.64</i>

per
per 730 mil gals (Annual Facility Production) per 2 mil gals (Reference Quantity)

Commercial Benchmark Technology - Capital Expenses (CapEx)

CapEx Category	Examples	Capital Expense Items (descriptions)	Purchase Price (\$)	Expected Equipment Lifetime (years)	Annual Capital Cost for Facility (\$)	Scaled Annual Capital Cost (\$ (Adjusted to new tech. facility size))	Capital Cost for Functional Unit (\$)
Process Equipment	furnaces, reactors	<i>Evap. Condensers</i>	<i>\$1,000,000</i>	<i>25</i>	<i>\$40,000</i>	<i>\$40,000</i>	<i>\$109.59</i>
Process Equipment Total:					<i>\$40,000</i>	<i>\$40,000</i>	<i>\$109.59</i>
Non-process Equipment	piping, control systems, power equipment.	<i>Piping</i>	<i>\$50,000</i>	<i>35</i>	<i>\$1,429</i>	<i>\$1,429</i>	<i>\$3.91</i>
Non-Process Equipment Total:					<i>\$1,429</i>	<i>\$1,429</i>	<i>\$3.91</i>
Engineering & Construction	engineering, design, procurement, construction	<i>Design</i>	<i>\$10,000</i>	<i>25</i>	<i>\$400</i>	<i>\$400</i>	<i>\$1.10</i>
		<i>Installation</i>	<i>\$500,000</i>	<i>25</i>	<i>\$20,000</i>	<i>\$20,000</i>	<i>\$54.79</i>
Engineering & Construction Total:					<i>\$20,400</i>	<i>\$20,400</i>	<i>\$55.89</i>
Other CapEx	land, commissioning, contingency, spare parts.						
Other CapEx Total:					<i>\$61,829</i>	<i>\$61,829</i>	<i>\$169.39</i>
Total Capital Expense:							
Annual Capital Equipment/Facility Maintenance (typical value 5%):					5%	5%	5%
Total Capital Expense, Including Maintenance:					<i>\$64,920</i>	<i>\$64,920</i>	<i>\$169.39</i>

per
per 730 mil gals (Annual Facility Production) per 730 mil gals (Scaled Facility Production, New Tech Equivalent) per 2 mil gals (Reference Quantity)

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Next, the costs and associated expected lifetime for the necessary system components are added.

Keep in mind that the level of granularity of the capital expenses for the new technology must be equal to that of the benchmark to ensure a fair cost comparison.

Economic Considerations:

OpEx

Models the cost of operating the technology required to produce the established functional unit.

Some inputs in this tab may not be applicable.

U.S. DEPARTMENT OF ENERGY (DOE) OFFICE OF ENERGY EFFICIENCY AND RENEWABLE ENERGY (EERE)														
Techno-economic, Energy & Carbon Heuristic Tool for Early Stage Technologies (TECHTEST)														
										Return to Planning Page				
Manufacturing Operating Expenses (OpEx)														
In this tab, you will estimate operating expenses (OpEx - i.e., recurring costs) for the new technology (left) and for the commercial benchmark (right), and energy costs were calculated in prior tabs and data are reproduced here for convenience (entries may be edited directly in the Raw Materials and optional) other recurring costs in the blue cells of this tab. In estimates, consider the annual costs for a facility of the size indicated in the CapEx tab facility production quantities (as entered into the CapEx tab) are shown below for each technology.														
New Technology (at Industrial Scale)														
Technology Name	Waste Heat Recovery (Heat Pump)										Techno			
Specific Product	Cooled Waste Water										Specific			
Reference Production Quantity	2.00	Million Gallons									Referen			
Annual Facility Production Quantity	730.00	Million Gallons									Annual			
	(quantity)	(units)												
Direct Labor Costs														
Estimate annual direct (operating) labor costs in the blue cells below, considering a facility of the size and annual production indicated in the CapEx employees and annual pay rates. If data are available as a total annual labor cost instead, data may be entered directly in the "Labor Cost (\$)" (per year) section. The default percentage for fringe benefits and general overhead is 72% (considered a typical value) but this can be overwritten if needed.														
If labor costs are unknown, rules-of-thumb based estimation methods may be used. See the tab linked below for rules of thumb (and a calculator tool).														
Calculation Tool: Labor Cost Estimation Rules-of-Thumb														
TECHTEST Landing Page	Full Entry Home Page	Rapid Data Entry Home Page	Project Basics & Benchmarks	Market	Functional Unit	Raw Materials	Manufacturing Energy	Use Phase Energy	CapEx	CapEx	Unit Conversion	Grid Mix Customization	Summary Tables	Results Dashboard

The OpEx (or operating expenses) tab models the cost of operating the technology required to produce the established functional unit. Depending on your project scope, some inputs in this tab may not be applicable.

Direct Labor Costs
 Estimate annual direct (operating) labor costs in the blue cells below, considering a facility of the size and annual production indicated in the CapEx tab. By default, annual costs are calculated from the number of full-time-equivalent (FTE) employees and annual pay rates. If data are available as a total annual labor cost instead, data may be entered directly in the "Labor Cost (\$ (per year))" column, over-writing the default formulas. Do not include administrative labor in this section. The default percentage for fringe benefits and general overhead is 72% (considered a typical value) but this can be overwritten if needed.
 If labor costs are unknown, rules-of-thumb based estimation methods may be used. See the tab linked below for rules of thumb (and a calculator that will aid you in completing this section).
 Calculation Tool: Labor Cost Estimation Rules-of-Thumb

New Technology - Direct Labor Costs

	Number of FTE Employees	Average Annual Pay Rate	Employee Fringe Benefits & General Overhead Rate (%)	Annual Labor Cost (\$ (for facility size shown above))	Labor Cost (\$ (per reference quantity))
Direct Labor (equipment operators & supervisors)	0.0096	\$75,000	72%	\$1,240	\$3.40
Total Operating Labor Cost:				\$1,240	\$3.40
				per 730 Million gallons (Annual Facility Production)	per 2 Million Gallons (Reference Quantity)

Commercial Benchmark - Direct Labor Costs

	Number of FTE Employees	Average Annual Pay Rate	Employee Fringe Benefits & General Overhead Rate (%)	Annual Labor Cost (\$ (for facility size shown above))	Scaled Annual Labor Cost (\$ (adjusted to new tech. facility size))	Labor Cost (\$ (per reference quantity))
Direct Labor (equipment operators & supervisors)	0.0332	\$75,000	72%	\$4,279	\$4,279	\$11.72
Total Operating Labor Cost:				\$4,279	\$4,279	\$11.72
				per 730 Million gallons (Annual Facility Production)	per 730 Million gallons (Scaled Facility Production, New Tech Equivalent)	per 2 Million Gallons (Reference Quantity)

Other Recurring Costs
 In this optional section, enter any other significant recurring costs (not listed in the Labor, Materials, or Energy categories above) in the table below. Estimate data on an annual basis, considering a facility of the size indicated earlier. Credits (e.g., refunds from tax incentives, money received from sale of secondary products or spent materials) may also be provided in this table as negative values, if applicable.

Note on Overhead: most indirect costs such as supplies, property tax, and R&D are now excluded by default in TECHTEST. Accurate estimation of indirect costs for early-stage technologies can be challenging, and it would be unusual for these costs to drive major differences between the new technology and commercial benchmark. Including these costs generally does not significantly affect comparisons between technologies. However, if data are available, indirect costs may be included in this table for completeness. General overhead, employee fringe benefits, and facility/equipment maintenance costs are addressed elsewhere in TECHTEST (in the Labor and CapEx sections) and should not be duplicated here.

New Technology - Other Recurring Costs

Recurring Cost (description)	Annual Recurring Cost (\$)	Recurring Cost (\$ (per reference quantity))
Lubrication & Maintenance Services	\$5,000	\$13.70
Total Other Recurring Cost:		\$5,000
		per 730 Million gallons (Annual Facility Production)

Commercial Benchmark - Other Recurring Costs

Recurring Cost (description)	Annual Recurring Cost (\$)	Scaled Annual Other Recurring Cost (\$ (adjusted to new tech. facility size))	Recurring Cost (\$ (per reference quantity))
Water treatment management for cooling water supplied to condensers	\$12,000	\$12,000	\$32.88
Total Other Recurring Cost:		\$12,000	\$32.88
		per 730 Million gallons (Annual Facility Production)	per 730 Million Gallons (Scaled Facility Production, New Tech Equivalent)

TECHTEST Landing Page	Full Entry Home Page	Rapid Data Entry Home Page	Project Basics & Benchmarks	Market	Functional Unit	Raw Materials	Manufacturing Energy	Use Phase Energy	CapEx	OpEx	Unit Conversion	Grid Mix Customization	Summary Tables	Results Dashboard
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Data inputs include the direct labor costs, along with any other recurring costs required to operate or create the technology.

In our example, there are more system aspects to manage with the benchmark technology, so the number of full-time employees will be higher.

Raw Materials Costs						Commercial Benchmark - Raw Material Inputs						
Materials costs entered into the "Raw Materials" tab are reprinted here for convenience. If data need to be adjusted, make changes in the Raw Materials tab.												
New Technology - Raw Material Inputs						Commercial Benchmark - Raw Material Inputs						
Material Inputs (list)	Amount of Material (to produce reference quantity)	unit	Specific Cost (\$/unit) (for this material)	Annual Materials Cost (\$) (per year)	Materials Cost (\$) (per reference quantity)	Material Inputs (list)	Amount of Material (to produce reference quantity)	unit	Specific Cost (\$/unit) (for this material)	Annual Materials Cost (\$) (per year)	Scaled Annual Materials Cost (\$) (adjusted to new tech. facility size)	Materials Cost (\$) (per reference quantity)
Lubrication (to run Fans)	2.34	kg	\$6.00	\$5,125	\$14.04	City water supply to evaporative condensers	17010.30928	gallons	\$0.002	\$12,417.53	\$12,418	\$34.02
Copper	0.367303562	kg		\$0	\$0.00	Biocide chemical addition to cooling loop for micro mitigation	3.322326031	gallons	\$19.09	\$23,150.57	\$23,151	\$63.43
Elastomer	0.160569863	kg		\$0	\$0.00	Steel low Alloy	0.317497841	kg		\$0.00	\$0.00	\$0.00
HDPE	0.005017808	kg		\$0	\$0.00	Stainless Steel	0.349464668	kg		\$0.00	\$0.00	\$0.00
Low alloyed steel	0.321139726	kg		\$0	\$0.00	Aluminium	0.398757315	kg		\$0.00	\$0.00	\$0.00
Lubricating Oil (Manufacturing)	0.027096164	kg		\$0	\$0.00	Bricks	0.346265477	Bricks		\$0.00	\$0.00	\$0.00
PVC	0.016056986	kg		\$0	\$0.00	Methacrylate	0.288178188	kg		\$0.00	\$0.00	\$0.00
Reinforced Steel	1.304630137	kg		\$0	\$0.00	Polyurethane	0.025744085	kg		\$0.00	\$0.00	\$0.00
						PVC	0.495184723	kg		\$0.00	\$0.00	\$0.00
Total Materials Cost:				\$5,125	\$14.04	Total Materials Cost:				\$35,568	\$35,568	\$97.45
				730 Million Gallons (Annual Facility Production)	2 Million Gallons (Reference Quantity)					730 Million Gallons (Annual Facility Production)	730 Million Gallons (Scaled Facility Production, New Tech Equivalent)	2 Million Gallons (Reference Quantity)

Will auto-populate

Energy Costs					Commercial Benchmark - Energy Cost Data					
Energy costs entered into the "Manufacturing Energy" tab are reprinted here for convenience. If data need to be adjusted, make changes in the Manufacturing Energy tab.										
New Technology - Energy Cost Data					Commercial Benchmark - Energy Cost Data					
Energy Source	Onsite Energy Consumption (MMBtu) (to produce reference quantity)	unit	Annual Energy Cost (\$)	Energy Cost (\$) (per reference quantity)	Energy Source	Onsite Energy Consumption (MMBtu) (to produce reference quantity)	unit	Annual Energy Cost (\$)	Scaled Annual Energy Cost (\$) (adjusted to new tech. facility size)	Energy Cost (\$) (per reference quantity)
Electricity	0.00	MMBtu	\$37	\$0.10	Electricity	0.37	MMBtu	\$2,851	\$2,851.15	\$7.81
Petroleum	0.01	MMBtu		\$0.00	Petroleum	0.01	MMBtu			\$0.00
Coal	0.01	MMBtu		\$0.00	Coal	0.01	MMBtu			\$0.00
Natural Gas	0.01	MMBtu	\$28	\$0.08	Natural Gas	0.01	MMBtu	\$28	\$28.23	\$0.08
Renewable Sources	0.00	MMBtu		\$0.00	Renewable Sources	0.00	MMBtu			\$0.00
Steam	0.00	MMBtu		\$0.00	Steam	0.00	MMBtu			\$0.00
Custom Inputs	0.00	MMBtu		\$0.00	Custom Inputs	0.00	MMBtu			\$0.00
Total Energy Cost:			\$65	\$0.18	Total Energy Cost:			\$2,879	\$2,879.38	\$7.89
			730 Million Gallons (Annual Facility Production)	2 Million Gallons (Reference Quantity)				730 Million Gallons (Annual Facility Production)	730 Million Gallons (Scaled Facility Production, New Tech Equivalent)	2 Million Gallons (Reference Quantity)

Costs that we entered earlier on the raw materials and manufacturing energy tabs will auto-populate the lower tables to give a full cradle-to-gate picture. And note that these data inputs are to be entered based on a facility's annual production basis.

OpEx Summary

New Technology: Heat Pump

New Technology - OpEx Summary

Waste Heat Recovery (Heat Pump)		
OpEx Category	Annual Recurring Cost (\$)	Recurring Cost (\$) (per reference quantity)
Direct Labor Cost	\$1,240	\$3.40
Raw Materials Cost	\$5,125	\$14.04
Energy Cost	\$65	\$0.18
Other Recurring Costs	\$5,000	\$13.70
Total Operating Expense	\$11,430	\$31.32
	per 730 Million Gallons (Annual Facility Production)	per 2 Million Gallons (Reference Quantity)

Benchmark: Evaporative Condenser

Commercial Benchmark - OpEx Summary

Evaporative Condenser			
OpEx Category	Annual Recurring Cost (\$)	Scaled Annual Recurring Cost (\$) (adjusted to new tech. facility size)	Recurring Cost (\$) (per reference quantity)
Direct Labor Costs	\$4,279	\$4,279	\$11.72
Raw Materials Costs	\$35,568	\$35,568	\$97.45
Energy Costs	\$2,879	\$2,879	\$7.89
Other Recurring Costs	\$14,738	\$14,738	\$40.38
Total Operating Expense	\$57,464	\$57,464	\$157.44
	per 730 Million Gallons (Annual Facility Production)	per 730 Million Gallons (Scaled Facility Production, New Tech Equivalent)	per 2 Million Gallons (Reference Quantity)

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We can now see a full summary of the operating expenses for the two technologies in the OpEx Summary section, with a significant improvement anticipated for the new heat pump technology.

Project Basics

Grid Mix Customization

Allows customization of the electricity grid mix based on the generation technologies used.

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Techno-economic, Energy & Carbon Heuristic Tool for Early Stage Technologies (TECHTEST)

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Grid Mix Customization

On this page, you can customize the grid mix used in the calculation of electricity generation emissions in the TECHTEST tool. The specific Grid Mix is an estimation of various energy sources used to create powerline electricity. The 2022 current US grid mix is the default. A Moderate and Net Zero scenario are also included, and using the "Choose Grid Mix" dropdown menu.

Choose Grid Mix (select from dropdown) **2022 Default**

Electricity Generation Technology	Fraction of Total	Life-Cycle Electricity generation emissions (lb CO2-eq/MMBtu electricity generated) based on IPCC data	Default CO2-eq/MMBtu data
Electricity Generation Technologies			
Fossil Fuels	21.9%	234.36	234.36
Coal	0.5%	177.08	177.08
Petroleum	38.3%	130.62	130.62
Natural Gas	0.3%	127.13	127.13
Other Gases	18.9%	7.76	7.76
Renewables	6.3%	15.52	15.52
Nuclear	0.9%	148.75	148.75
Hydropower	0.5%	148.75	148.75
Biomass - Wood	0.4%	24.58	24.58
Biomass - Waste	2.8%	31.04	31.04
Geothermal	9.2%	7.11	7.11
Solar			
Wind			
100.0%			
Weighted average emissions for U.S. electricity generation:		108.6 lb CO2-e	

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One final tab before heading into our results is the Grid Mix Customization tab, which allows customization of the electricity grid mix based on the generation technologies used, including fossil fuels and renewable sources.

Choose Grid Mix
(select from dropdown)

2022 Default



2022 Default

Custom

Moderate

Net Zero




Custom Value Selector <i>(Only use for selecting custom grid mix)</i>			
Electricity Generation Technology			Life-Cycle Electricity generation emissions (lb CO2-eq/MMBtu electricity generated) based on IPCC data
Electricity Generation Technologies	Fossil Fuels	Coal	234.36
		Petroleum	177.08
		Natural Gas	130.62
		Other Gases	127.13
	Renewables	Nuclear	7.76
		Hydropower	15.52
		Biomass - Wood	148.75
		Biomass - Waste	148.75
		Geothermal	24.58
		Solar	31.04
Wind	7.11		
			0.0%
<i>Weighted average emissions for U.S. electricity generation:</i>			0.0 lb CO2-e

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The Choose Grid Mix dropdown menu allows you to choose between three preset scenarios: a 2022 U.S. Default scenario, a hypothetical Moderate scenario (on the way to Net Zero), and a Net Zero scenario that consists almost entirely of renewables. There is also a Custom option, which can be used to manually edit the mix of energy generation technologies and emissions.

Project Basics

1. Project Basics & Benchmarks
2. Market
3. Functional Unit
4. Grid Mix Customization



Economic Considerations

1. CapEx
2. OpEx



Life Cycle Impacts

1. Raw Materials
2. Manufacturing Energy
3. Use Phase Energy



Results

1. Summary Tables
2. Results Dashboard

Once all the previous sections have been completed, the results from our TECHTEST analysis can be viewed in table and graph form.

Results

Summary Tables

Shows detailed costs, energy use, and emission of each aspect of the manufacturing and use processes.

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Results Summary Tables

This worksheet auto-calculates. Do not enter data in this tab. After entering data into the data input tabs, results will appear in the green cells of the summary tables.

Project Basics	Project Title	Waste Heat Recovery Cooling in Beverage Manufacturing		
	Lead Organization	Hypothetical Organization		
	Collaborative Partner(s)	Staff		
	Principal Investigator	John Doe, Hypotential National Laboratory		
	AMO Technology Manager	Jane Doe		
	Project Timeline	January 2023 to January 2025		
	Funding Mechanism	R&D Project		
End-Use Market	Market End-Use Product	Cooled Waste Water		
	Current Annual US Production	7,300,000	Million Gallons	
	U.S. Production that Could be Replaced by New Technology	7,300,000	Million Gallons	(assuming replacement of 100%)
	U.S. Potential Production using New Technology	7,300,000	Million Gallons	(based on substitution ratios)
Benchmarking		Technology Definition(s)	Product or Application	Current Technology Status
	New Technology (developed in this project)	Waste Heat Recovery (Heat Pump)	Cooled Waste Water	Typical Technology
	Commercial Benchmark (used in comparisons)	Evaporative Condenser	Cooled Waste Water	Typical Technology
	Other Competing Technologies (list)			

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The Summary Tables tab shows the detailed costs, energy use, and emissions of each aspect of the manufacturing and use processes.

Manufacturing Cost Results

Manufacturing Cost Comparison
Based on Equivalent Reference Quantity

		New Technology, at Industrial Scale	Commercial Benchmark
		Waste Heat Recovery (Heat Pump)	Evaporative Condenser
Technology Name		2 Million Gallons of Cooled Waste Water	2 Million Gallons of Cooled Waste Water
Reference Quantity			
Manufacturing Cost (\$) for Functional Unit			
Capital Expenses (CapEx)	Process Equipment	\$69.67	\$109.59
	Non-process Equipment	\$3.91	\$3.91
	Engineering & Construction	\$25.05	\$55.89
	Other Capital Expenses		
		\$4.93	\$8.47
Operating Expenses (OpEx)	Raw Materials	\$14.04	\$97.45
	Energy	\$0.18	\$7.89
	Direct Labor	\$3.40	\$11.72
	Other Recurring Costs	\$13.70	\$32.88
Total CapEx Subtotal		\$108.75	\$186.76
Total OpEx Subtotal		\$31.32	\$149.94
Total Cost (CapEx + OpEx)		\$140.06	\$336.69

Life Cycle Comparison

Based on Overall Potential U.S. Market (Cradle to Grave)

		New Technology		Commercial Benchmark	
		Waste Heat Recovery (Heat Pump)		Evaporative Condenser	
Technology Name		7,300,000 Million Gallons of Cooled Waste Water		7,300,000 Million Gallons of Cooled Waste Water	
Production Quantity					
		Energy	Emissions (100-yr GWP)	Energy	Emissions (100-yr GWP)
Cradle-to-Gate Energy**	Raw Materials	0.9 TBtu	0.0 million tons CO2-e	1.7 TBtu	0.1 million tons CO2-e
	Manufacturing	0.1 TBtu	0.1 million tons CO2-e	3.9 TBtu	0.1 million tons CO2-e
Gate-to-Grave***	Use Phase	86.4 TBtu	-8.7 million tons CO2-e	127.5 TBtu	2.4 million tons CO2-e
	Cradle-to-Gate Subtotal	1.0 TBtu	0.1 million tons CO2-e	5.6 TBtu	0.2 million tons CO2-e
Total Energy	Gate-to-Grave Subtotal	86.4 TBtu	-8.7 million tons CO2-e	127.5 TBtu	2.4 million tons CO2-e
	Total Energy (Cradle-to-Grave)	87.4 TBtu	-8.5 million tons CO2-e	133.1 TBtu	2.6 million tons CO2-e

** Cradle-to-gate energy is computed in terms of the total annual U.S. production ("overnight replacement" scenario or current).

*** Gate-to-grave energy is computed in terms of the overall fleet of products in use ("overnight replacement" scenario or current).

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This tab is great for examining how the contributions from each section contribute to the overall picture, and for directly comparing lifecycle steps.

If the new technology were immediately and fully deployed at its maximum U.S. market share (i.e. in the "overnight replacement" scenario), the annual potential cost savings for U.S. manufacturers is:

\$717,697,610 Annual Potential Cost Savings to U.S. Manufacturers
(58.4% cost savings for production replaced)

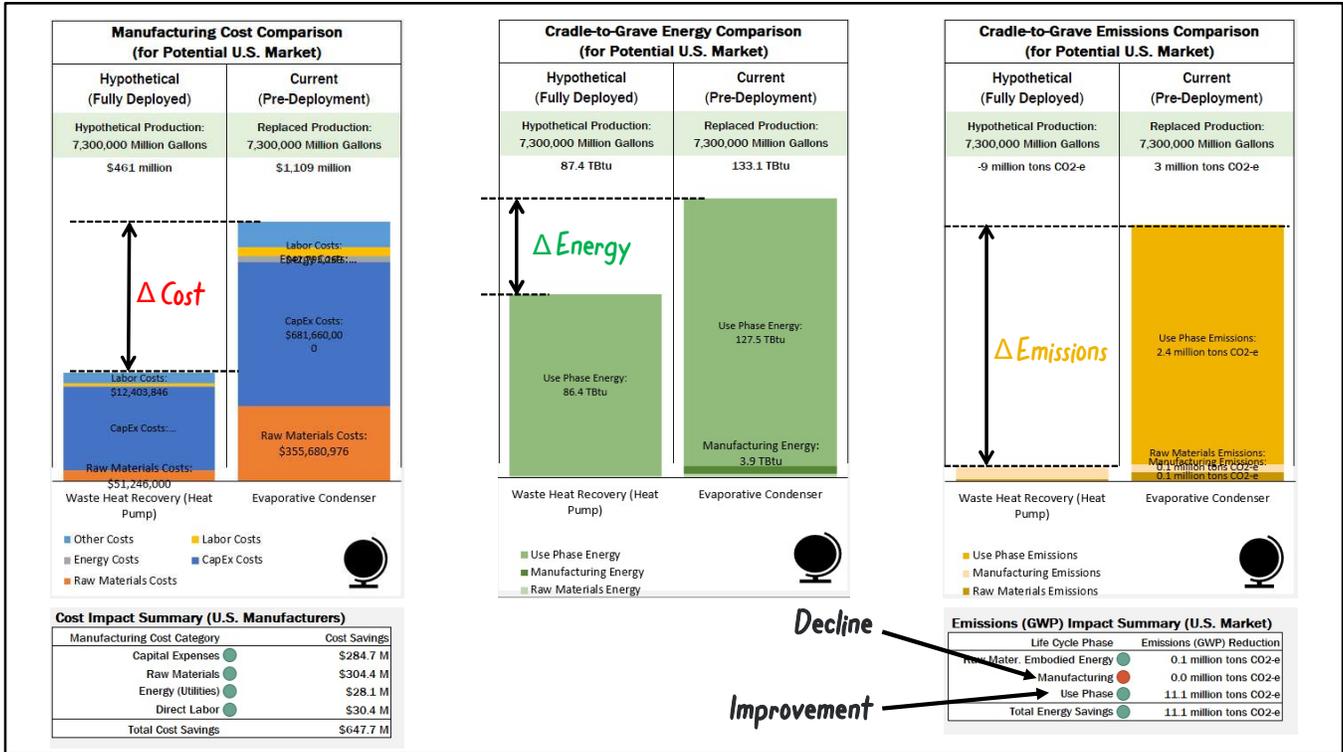
If the new technology were immediately and fully deployed at its maximum U.S. market share (i.e. in the "overnight replacement" scenario), the annual potential life cycle energy & emissions impact for the U.S. market is:

45.6 TBtu Annual Potential U.S. Lifetime Energy Savings
(34.3% energy savings in affected markets)

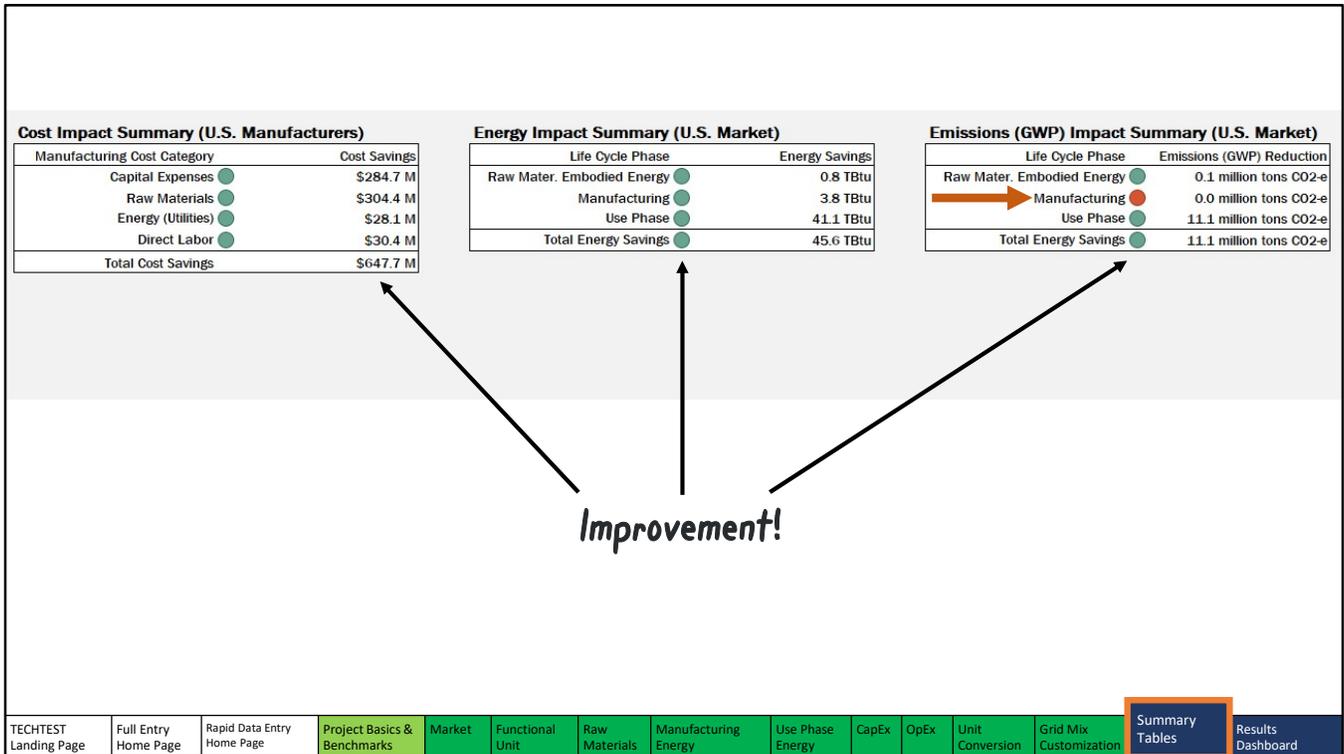
11.12 million tons CO2-e Annual Potential U.S. Emissions Reduction
(429.0% emissions reduction in affected markets)

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Looking at the results presented in bolded green text, we can see that our proposed technology offers the potential for significant cost savings, energy savings, and emissions reduction.



The Results Dashboard tab presents the big-picture results of our TECHTEST analysis in graphical form, displaying charts of cost, energy, and emissions for both the reference volume and the overall U.S. market. Results are broken down by contribution, and improvements and declines can be seen as green and red circles, respectively, in the lower tables.



In our example, we can see a consistent improvement with the new technology. The only area in which the heat pump underperforms is the manufacturing phase, where released refrigerants weaken its performance. Luckily, the manufacturing phase is a tiny contribution to the whole picture, and the heat pump ends up being a much better performer in the long run.

*Thanks for
watching!*

In this video, we explored the TECHTEST tool and its capabilities for analyzing the energy, emissions, and cost-saving opportunities of early-stage technologies.

Please check out our other videos in this series to learn more tools and techniques for evaluating costs and environmental impacts of early-stage technologies.



In this video, we explored the TECHTEST tool and its capabilities for analyzing the energy, emissions, and cost-saving opportunities of early-stage technologies. This tool was designed to offer a flexible degree of granularity when comparing new and benchmark technologies, while providing clear, detailed results about the opportunities presented by these new approaches.

We hope you've found this video helpful in orienting yourself with the TECHTEST tool. Check out our other videos in this series to learn more tools and techniques for evaluating costs and environmental impacts of early-stage technologies. Thanks for watching!